FINAL

PHASE I
REMEDIAL INVESTIGATION REPORT

FOR

RAMSDELL QUARRY LANDFILL
AT THE
RAVENNA ARMY AMMUNITION PLANT,
RAVENNA, OHIO

PREPARED FOR

US Army Corps of Engineers®

LOUISVILLE DISTRICT
CONTRACT No. GS-10F-0076J
DELIVERY ORDER W912QR-05-F-0033

September 2005

SAIC

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contributed to the preparation of this document and should not
be considered an eligible contractor for its review.

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Science Applications International Corporation (SAIC) has completed the Final Report for the Phase I Remedial Investigation for the Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumptions; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

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CONTENTS

FIGURES

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TABLES

ACRONYMS

ALM	Adult Lead Methodology
amsl	above mean sea level
AOC	area of concern
AT123D	Analytical Transient 1-, 2- ,3-Dimensional model
BERA	baseline ecological risk assessment
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	contaminant migration contaminant of concern
CMCOPC	contaminant migration contaminant of potential concern
COC	chemical of concern
COI	chemical of interest
COPC	chemical of potential concern
COPEC	contaminant of potential ecological concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSF	cancer slope factor
CSM	conceptual site model
DAD	dermally adsorbed dose
DAF	dilution attenuation factor
DLF	dust-loading factor
DNB	dinitrobenzene
DNT	dinitrotoluene
DQA	data quality assessment
DQO	data quality objective
EPA	U. S. Environmental Protection Agency
EPC	exposure point concentration
ESA	Endangered Species Act
ESV	ecological screening value
ERA	ecological risk assessment
EU	exposure unit
FS	feasibility study
FWHHRAM	*Facility-wide Human Health Risk Assessor Manual*
GAF	gastrointestinal absorption factor
GPL	GPL Laboratories, Inc.
GSSL	generic soil screening level
HEAST	Health Effects Assessment Summary Tables
Heritage	Heritage Program
HHRA	human health risk assessment
HI	hazard index
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HQ	hazard quotient
ID	identifier
IEUBK	Integrated Exposure Uptake Biokinetic
ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
JMC	Joint Munitions Command
LCS	laboratory control sample

LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
MDC	maximum detected concentration
MDL	method detection limit
MEC	munitions and explosives of concern
NEPA	National Environmental Policy Act
NFA	no further action
NGB	National Guard Bureau
NOAEL	no observed adverse effect level
NSCORP	Norfolk Southern Corporation
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ODOW	Ohio Department of Wildlife
OHARNG	Ohio Army National Guard
Ohio EPA	Ohio Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon
PbB	blood lead
PBT	persistent, bioaccumulative, and toxic compound
PCB	polychlorinated biphenyl
PEF	particulate emission factor
PID	photoionization detector
PRG	preliminary remediation goal
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RAGS	*Risk Assessment Guidance for Superfund*
RBC	risk-based concentration
RME	reasonable maximum exposure
RDA	recommended daily allowance
RDI	recommended daily intake
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RfC	reference concentration
RfD	reference dose
RGO	remedial goal option
RI	remedial investigation
RQL	Ramsdell Quarry Landfill
RRSE	Relative Risk Site Evaluation
RTLS	Ravenna Training and Logistics Site
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SERA	screening ecological risk assessment
SESOIL	Seasonal Soil Compartment model
SMDP	Scientific Management Decision Point
SOP	standard operating procedure
SRC	site-related contaminant
SRV	screening reference value
SVOC	semivolatile organic compound
T&E	threatened and endangered
TAL	target analyte list
TEF	toxicity equivalency factor

THI	target hazard index
TNT	trinitrotoluene
TR	target risk
UCL_{95}	95% upper confidence limit
USACE	U. S. Army Corps of Engineers
USGS	U. S. Geological Survey
VOC	volatile organic compound
WBG	Winklepeck Burning Grounds
WOE	weight of evidence
WQC	water quality criteria

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EXECUTIVE SUMMARY

This Phase I Remedial Investigation (RI) Report characterizes the nature and extent of contamination, evaluates the fate and transport of contaminants, and assesses potential risk to human health and the environment resulting from former operations at the Ramsdell Quarry Landfill (RQL) at the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. The Phase I RI was conducted under contract to the U. S. Army Corps of Engineers (USACE), Louisville District for the RVAAP Installation Restoration Program (Contract No. F44650-D-99-0007, Delivery Order CY11). This Phase I RI Report was subsequently completed under subcontract to USACE, Louisville District under Contract No. GS-10F-0076J, Delivery Order W912QR-05-F-0033.

The primary objectives of the Phase I RI are as follows:

- Abandonment of existing monitoring wells MW-1, -2, -3, -4, and -5.
- Install additional monitoring wells downgradient (north-northwest) of the area of concern (AOC) to bound the extent of contamination observed in groundwater adjacent to the quarry and to further evaluate potentiometric gradient reversal, observed previously adjacent to the quarry.
- Install additional monitoring wells upgradient (south-southeast) of the AOC to identify if any potential migration of contaminants from Load Line 1 is occurring, which might account for contaminants observed at RQL.
- Conduct multiple sampling rounds of newly installed wells under both base flow/dry conditions and high flow/storm event conditions to determine if storm-induced flushing and transport of contaminants is occurring.
- Utilize existing data (surface water, sediment, and groundwater) and surface soil data acquired under the Phase I RI to complete a human health risk assessment (HHRA) in accordance with Ravenna facility-wide risk assessment guidance (USACE 2003a) and an Ohio Level II ecological risk assessment (ERA).
- Conduct surface soil sampling using multi-increment sampling techniques to evaluate the methodology, the feasibility of the method for characterizing AOCs, and the future application of this sampling technique at RVAAP.
- Conduct surface soil sampling within the bottom of the quarry using discrete samples to address a data gap remaining from previous site characterization efforts.
- Evaluate contaminate fate and transport and update the conceptual site model (CSM) using newly acquired Phase I RI data.

PREVIOUS INVESTIGATIONS

The Phase I RI at Ramsdell Quarry was designed to collect data to supplement information obtained from a two-phased previous investigation at the site:

1. Initial Phase Groundwater Investigation Report (USACE 1999), and
2. Final Phase Groundwater Investigation Report (USACE 2000).

The Groundwater Investigation initial phase, conducted in July 1998, involved: (1) the installation and sampling of six new monitoring wells; (2) sampling of the existing RQL post-closure monitoring well system; (3) sampling of sediment and surface water within the quarry; and (4) construction of a staff gauge within the main quarry pond.

The follow-on phase of the Groundwater Investigation, which extended until July 15, 1999, included: (1) quarterly, dry season and wet season (storm event) sampling of the new monitoring well network and quarry pond surface water; (2) collection of long-term water levels from the new monitoring well network and quarry pond; (3) monthly manual water level measurements from all wells and the pond staff gauge; and (4) collection of precipitation data.

Groundwater samples from these two phases of investigation contained low but detectable concentrations of nine explosive compounds, associated degradation products, and nitroglycerine. Multiple trace metals were present above facility-wide background criteria, as well as Ohio drinking water standards [maximum contaminant levels (MCLs)] in both filtered and unfiltered samples. The most prevalent metals were aluminum, arsenic, cobalt, manganese, mercury, nickel, and zinc. Sporadic detections of bis(2ethyl-hexyl)phthalate and volatile organic compounds (VOCs) (most commonly toluene and methylene chloride) were noted. VOC concentrations did not exceed MCLs. The upgradient well (RQLmw-006) and two other wells (RQLmw-007 and -008) located at the toe of the landfill typically had the highest percentages of detected contaminants. Water level data collected during the investigations showed that horizontal potentiometric gradients are consistently to the northeast across the site.

AVAILABLE DATA

RQL remained relatively undisturbed between the Groundwater Investigation and Phase I RI. Previous sediment data are assumed to still be representative of current site conditions and selected samples considered as dry sediments are included in the Phase I risk evaluations. Historical groundwater data were not included for quantitative evaluation purposes because of their age. However, groundwater monitoring well data from the previous investigation were used qualitatively to identify and evaluate any contaminant trends over time.

The data collected under this Phase I RI include:

- ten surface soil samples [0 to 1 ft below ground surface (bgs)];
- five multi-increment surface soil samples (0 to 1 ft bgs); and
- six groundwater samples.

Slug tests were performed at newly installed monitoring wells to determine the hydraulic conductivity of the geologic materials surrounding each well screen.

NATURE AND EXTENT

Surface Soil Discrete Samples

All discrete surface soil samples were analyzed for explosives, target analyte list (TAL) metals, cyanide, and semivolatile organic compounds (SVOCs); two discrete samples were analyzed for propellants; and one discrete sample was analyzed for VOCs and pesticides/polychlorinated biphenyls (PCBs). Explosives and propellants were detected at four discrete surface soil sample sites, RQL-025, -026, -027 and -030. Fourteen inorganic analytes were identified as site-related contaminants (SRCs), including antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, thallium, and zinc. Site RQL-026 in the northwest area of the quarry had the highest number of metals exceeding background concentrations (16). The sites with the lowest number of metals exceeding background concentrations were RQL-025 (four) in the northern area of the site and RQL-032 (five) in the southern area of the site. There were 20 SVOCs detected and SVOCs were detected at all sites. The maximum detected concentrations (MDCs) for nearly all SVOCs were observed at RQL-026 in the northwest corner of the area. No VOCs, pesticides, or PCBs were detected.

Surface Soil Multi-increment Samples

The bottom of Ramsdell Quarry, exclusive of the pond and landfill toe slope, was divided into approximately five equal areas. One multi-increment composite sample was collected from each of the five separate areas. Multi-increment samples were analyzed for explosives, TAL metals, cyanide, and SVOCs, and one multi-increment sample was also analyzed for propellants and pesticides/PCBs. Results from multi-increment samples were not aggregated and summary statistics were not calculated as was done for discrete samples. However, results were compared to facility-wide background values for evaluation purposes. Inorganic constituents were detected at all sites. The number of constituents that exceeded background concentrations ranged from 8 to 12, with antimony, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc all frequently observed above background. SVOCs were detected at all sites except RQL-038. The number of SVOCs detected ranged from 11 to 15. The maximum concentrations for nearly all analytes were observed at RQL-034. No explosives, propellants, pesticides, PCBs, or VOCs were detected.

Groundwater

Six new groundwater wells were installed and sampled during the Phase I investigation. A total of 12 metals were identified as SRCs, including aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc. Site RQLmw-013 had the highest number of SRCs detected (ten) followed by RQLmw-012 (nine). The well with the fewest SRCs detected (five) was RQLmw-014, which is the farthest downgradient well. The VOC carbon disulfide was detected at all six sites and is considered to be a SRC. No explosives, SVOCs, pesticides, or PCBs were detected in groundwater in any of the Phase I wells.

FATE AND TRANSPORT ANALYSIS

Contaminant fate and transport modeling performed as part of the Phase I RI included leachate modeling [Seasonal Soil Compartment (SESOIL)]. Groundwater modeling [Analytical Transient 1-, 2-, 3-Dimensional (AT123D)] was conducted from the source to selected receptors or exit points from the AOC. The receptor selected for groundwater transport modeling was the nearest perennial stream at its closest point downgradient of the AOC (unnamed tributary about 1,200 ft north of Ramsdell Quarry).

SESOIL Modeling

1,3-Dinitrobenzene (DNB); 2,6-dinitrotoluene (DNT); nitroglycerin; hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); antimony; arsenic; chromium; and carbazole were identified as final contaminant migration contaminants of potential concern (CMCOPCs) for RQL based on source loading predicted by the SESOIL modeling. In addition, manganese was detected in Phase I RI groundwater samples above its risk-based concentration (RBC) beneath the quarry, and it was identified as a final CMCOPC.

AT123D Modeling

Nitroglycerin, RDX, and carbazole were identified as contaminant migration contaminants of concern based on AT123D modeling. The maximum groundwater concentrations of these constituents were predicted to exceed MCLs or RBCs at the unnamed tributary at the closest point downgradient of the source areas.

HUMAN HEALTH RISK ASSESSMENT

The HHRA was conducted to evaluate risks and hazards associated with contaminated media at RQL for one representative receptor (Security Guard/Maintenance Worker) exposed to one medium and one exposure unit (surface soil, from a depth interval of 0 to 1 ft bgs). Direct contact (i.e., ingestion, dermal contact, and inhalation) exposure pathways were evaluated. In addition to the representative receptor described above, the other four receptors described in the *Facility-wide Human Health Risk Assessor Manual* [National Guard Dust/Fire Control Worker, National Guard Trainee, Hunter/Fisher, and Resident Subsistence Farmer (adult and child)] are evaluated for exposure to surface soil, groundwater, sediment, and surface water to provide additional information for evaluation in the feasibility study (FS) (e.g., to establish the need for institutional controls). These additional receptors are not anticipated at RQL due to physical constraints (e.g., wetlands, munitions and explosives of concern, and landfill) and intended future land use by the Ohio Army National Guard. The Resident Subsistence Farmer provides a baseline for evaluating this site with respect to unrestricted release. Remedial goal options (RGOs) were calculated for the Security Guard/Maintenance Worker and all other receptor scenarios.

One metal (arsenic), seven polycyclic aromatic hydrocarbons (PAHs) [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and one SVOC (carbazole) were identified as chemicals of concern (COCs) in surface soil for the representative receptor (i.e., Security Guard/Maintenance Worker) at RQL.

Risk-based RGOs were computed for all COCs at a risk level of 10^{-5} and a hazard index (HI) of 1. The exposure point concentrations (EPCs) for arsenic, benzo(*k*)fluoranthene, chrysene, and carbazole were all smaller than their associated most conservative risk-based RGO for the Security Guard/Maintenance Worker. The EPC for arsenic was also smaller than the surface soil background concentration for RVAAP. The MDCs for all eight organic COCs came from station RQL-026. The only sample location other than RQL-026 with a detected concentration larger than an RGO is RQL-025 [benzo(*a*)pyrene].

An additional two surface soil COCs are identified for the National Guard Trainee (chromium) and Resident Subsistence Farmer (2,6-DNT) exposure scenarios.

The Security Guard/Maintenance Worker is not exposed to groundwater, sediment, or surface water. COCs identified for these media for the other receptors evaluated are listed below.

- Two COCs (arsenic and manganese) were identified in groundwater.
- Four COCs [arsenic, chromium, manganese, and benzo(*a*)pyrene] were identified in sediment.
- Three COCs (arsenic, manganese, and aldrin) were identified in surface water.

SCREENING ECOLOGICAL RISK EVALUATION

The RQL site contains sufficient terrestrial and aquatic (soil, sediment, and surface water) habitat to support various classes of ecological receptors. The presence of suitable habitat and observed receptors at the site warrants a screening ERA (SERA). Thus, the Ohio Environmental Protection Agency (Ohio EPA) protocol (Level I) was met and Level II was needed. Also, the Army's RVAAP Facility-wide ERA Work Plan (USACE 2003a) has been used to guide the work.

Forty-eight chemicals were retained as constituents of potential ecological concern (COPECs) for surface soil. Thirty chemicals were retained as COPECs for sediment. Seventeen chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for soil, sediment, and surface water, ecological CSMs were prepared, along with the identification of site-specific ecological receptors, relevant and complete exposure pathways, and candidate assessment endpoints. These types of information will be used to prepare a Level III Baseline if it is deemed necessary to conduct a Level III ERA.

Based on the presence of multiple COPECs in soil, sediment, and surface water, as well as the presence of site-specific ecological receptors and complete exposure pathways to those COPECs at the RQL site, a recommendation is made to move to a Scientific Management Decision Point (SMDP). The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in Chapters 7.0 and 8.0, are: (1) risk management of the ecological resources based on the military land use or other reasons that many include development of RGOs or weight-of-evidence (WOE) analysis that no RGOs are required; (2) remediation of some of the source material, if required, to reduce ecological risks; or (3) conduct of more investigation, such as a Level III. In the FS, a WOE approach to the COPECs involved at RQL would assist in defining the best outcome or decision. Thus, the information in this Level II SERA can be used to assist risk managers in making their decision associated with the SMDP.

CONCEPTUAL SITE MODEL

A revised CSM is presented in Chapter 8.0 of this report that incorporates previous investigation results along with Phase I RI data, the results of contaminant fate and transport modeling, and risk evaluations. Elements of the CSM include:

- primary contaminant source areas and release mechanisms,
- contaminant migration pathways and exit points, and
- data gaps and uncertainties.

Three potential source terms were evaluated as part of the CSM: the former landfill, soil and sediment within the bottom of the quarry, and Load Line 1. The revised CSM confirms that groundwater flow is to the northeast and denotes that the maximum extent of contamination appears to be limited to the immediate vicinity of the AOC. Load Line 1 is determined not to be a likely source of explosives observed previously in well RQLmw-006 because Phase I RI wells installed further upgradient did not contain detectable levels of explosives. The revised CSM also identifies residual uncertainties based on available site characterization and chemical data.

CONCLUSIONS

The conclusions presented below, by medium, combine the findings of the contaminant nature and extent evaluation, fate and transport modeling, and the human health and ecological risk evaluations. To support remedial alternative selection and evaluation in future Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents (e.g., FS), RGOs were developed for identified COCs in surface soil, groundwater, sediment, and surface water at RQL at an HI of 1 or risk level of 10^{-5}.

Surface Soil

Explosives, metals, and SVOCs were detected above background in surface soil samples at RQL. Fate and transport modeling or monitoring data indicate that 1,3-DNB; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; chromium; manganese; and carbazole may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs. Of these CMCOPCs, nitroglycerin, RDX, and carbazole were predicted, based on AT123D modeling, to potentially exceed MCLs or RBCs at the unnamed tributary north of RQL at the closest point downgradient of the AOC. However, monitoring results from the Phase I RI do not indicate that such migration is occurring beyond the immediate vicinity of the AOC.

One metal (arsenic), seven PAHs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and one SVOC (carbazole) were identified as COCs in surface soil for the Security Guard/Maintenance Worker. The EPCs for arsenic, benzo(*k*)fluoranthene, chrysene, and carbazole were all smaller than their most conservative RGO at a target risk of 10^{-5}. The EPC for arsenic (15.3 mg/kg) was also smaller than the surface soil background concentration for RVAAP (15.4 mg/kg). Detected concentrations for all eight organic COCs at station RQL-026 exceeded RGOs. The only other Phase I RI sample location with a detected concentration greater than an RGO was station RQL-025 [benzo(*a*)pyrene].

Two additional surface soil COCs are identified for the National Guard Trainee (chromium) and Resident Subsistence Farmer (2,6-DNT) exposure scenarios.

Forty-eight chemicals were retained as COPECs for surface soil based on the Levels I and II SERA. Site-specific ecological receptors, relevant and complete exposure pathways, and candidate assessment endpoints were also identified.

Groundwater

Detected concentrations of metals above background criteria occur throughout Phase I groundwater wells at RQL; however, only three metals (arsenic, lead, and manganese) were found to exceed Region 9 preliminary remediation goals. The MDCs of arsenic and lead were well below Ohio MCLs and federal treatment standards. Carbon disulfide was detected in all six wells during the Phase I RI; however, this constituent is believed to be an analytical artifact based on its distribution. Furthermore, carbon disulfide was not detected in any wells during a subsequent wet season sampling event conducted in May 2004. Explosives, SVOCs, pesticides, and PCBs were not detected in any RQL groundwater monitoring well sample during the Phase I RI. The lack of explosives in Phase I RI wells indicates a limited extent of contaminant migration downgradient of the site and that Load Line 1 does not represent an upgradient source of contaminants to RQL.

The Security Guard/Maintenance Worker is not exposed to groundwater. Two COCs (arsenic and manganese) were identified in groundwater for the other receptors evaluated.

Sediment and Surface Water

The Security Guard/Maintenance Worker is not exposed to sediment or surface water. COCs identified for these media for the other receptors evaluated are listed below.

- Four COCs [arsenic, chromium, manganese, and benzo(*a*)pyrene] were identified in sediment.
- Three COCs (arsenic, manganese, and aldrin) were identified in surface water.

LESSONS LEARNED

A key project quality objective for the Phase I RI at RQL is to document lessons learned so that future projects may benefit from lessons learned and constantly improve data quality and performance. Lessons learned are derived from process improvements that were implemented or corrective measures for nonconformances.

- The presence of Ohio EPA and USACE staff on-site during field operations was beneficial in that potential changes to the project work plan due to field conditions could be quickly discussed, resolved, and implemented.

- The availability of on-site facilities for use as a field staging area and to house the field explosives laboratory was extremely beneficial. Having high-quality shelter facilities for sample storage and management operations, equipment decontamination, and the field laboratory improves sample quality and project efficiency. The facility provides a central and secure location to store equipment and supplies, as well as to conduct safety meetings and other site-specific training.

- Future planned well plugging and abandonment efforts should include compilation of detailed well construction information during the project scoping phase to the extent that such records are available. Field inspection of the wells to be plugged and abandoned, including sounding of well depths, is recommended to verify casing types and diameters and well depths. Such information will allow project teams to prepare and mobilize the necessary equipment to complete the plugging and abandonment task with as little downtime as possible due to unforeseen field conditions.

RECOMMENDATIONS

To provide decision makers with the information necessary to evaluate remedial alternatives to reduce or eliminate potential risks to human and/or ecological receptors, it is recommended that RQL proceed to the FS phase under the RVAAP CERCLA process. It is recommended that the FS phase employ a streamlined remedial alternatives evaluation process based on the most likely land use assumptions and evaluate a focused set of technologies, alternatives, and associated costs based on the most likely foreseeable land use. The intent of this strategy is to accelerate response complete or response in place for the AOC by focusing the FS efforts to appropriate remedies based on site conditions and land use considerations. RQL is an ideal candidate for a focused FS approach because of the limited extent of contamination and the presence of the landfill would effectively preclude most, if not all, land uses other than maintenance and monitoring. For surface water and groundwater, the FS for RQL should recognize and defer, if appropriate, to the separate facility-wide investigations for these integrator media.

Additional characterization of the AOC is not necessary, based on data obtained to date to proceed with the FS phase. Substantial data gaps have not been identified following completion of the Groundwater Investigation and Phase I RI. Long-term monitoring and reporting in compliance with Ohio solid waste regulations is anticipated to continue and should be considered when developing the path forward under the FS.

The future land uses and controls envisioned the AOC should be determined prior to selection of the path forward for the site. Establishment of the most likely land use scenario(s) will allow decision makers the initial information necessary to determine the correct remedial action land use controls, and/or continued monitoring, to achieve requisite protection of human health and the environment. The envisioned future use of the AOC, or a portion of the AOC, is an important consideration in determining the extent of remediation necessary to achieve the required degree of protectiveness. For example, a Security

Guard/Maintenance Worker land use scenario versus a National Guard Trainee scenario influences how much cleanup is needed to lower the risk to protective levels. Establishment of land use will also allow for streamlined evaluation of remedies and will be necessary for documentation in a Record of Decision, as applicable. Based on land use considerations, risk managers should identify the need for any additional human health risk evaluation or RGO development and whether further evaluation of ecological risks, as denoted in Chapter 7.0, may be required, or if ecological RGOs are required for the AOC.

Monitoring wells MW-1 through -5 are non-specification wells installed with long open intervals in the bedrock zone. The open intervals were largely backfilled prior to installing screens and casings. These long open boreholes represent potential pathways for movement of contaminants from fracture pathways in shallow bedrock intervals to deeper groundwater intervals. It is recommended that plugging and abandonment of these wells be completed upon availability of funding.

1.0 INTRODUCTION

This report documents the results of the Phase I remedial investigation (RI) at the Ramsdell Quarry Landfill (RQL) at the U. S. Army Joint Munitions Command (JMC) Ravenna Army Ammunition Plant, (RVAAP), Ravenna, Ohio (Figures 1-1 and 1-2). The Phase I RI was conducted under the U. S. Department of Defense Installation Restoration Program (IRP) by Science Applications International Corporation (SAIC) and its subcontractors, under contract number F44650-D-99-0007, Delivery Order No. CY11, with the U. S. Army Corps of Engineers (USACE), Louisville District. The Phase I RI was conducted in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 following work plans reviewed and commented on by the Ohio Environmental Protection Agency (Ohio EPA). This Phase I RI Report was subsequently completed under subcontract to USACE, Louisville District under Contract No. GS-10F-0076J, Delivery Order W912QR-05-F-0033.

This document summarizes the results of the Phase I RI field activities conducted from October 2003 through January 2004 at RQL. The field program, environmental setting, and nature and extent of contamination are discussed. Human health and ecological screening risk evaluations were performed as part of the Phase I RI. Results of the contaminant occurrence and distribution and risk evaluations are used to develop a conceptual site model (CSM) for RQL that summarizes the results of the investigation, presents conclusions, and forms the framework for decisions regarding future IRP actions at RQL.

1.1 PURPOSE AND SCOPE

Figure 1-3 presents the approach to implementing the CERCLA process under the guidance of the IRP. Priorities for environmental restoration at areas of concern (AOCs) at RVAAP are based on their relative potential threat to human health and the environment, derived from Relative Risk Site Evaluations (RRSEs). Thirty-eight AOCs were identified in the *Preliminary Assessment for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 1996). Thirteen new AOCs were identified in 1998 as a result of additional records searches and site walkovers. These were ranked by the U. S. Army Center for Health Promotion and Preventive Medicine and entered into the JMC database. Those AOCs ranked as high-priority sites (i.e., those with high RRSE scores) are targeted first for Phase I RIs. Medium- and low-priority sites will be characterized in Phase I RIs following completion of the RIs for high-priority AOCs. Investigations and remedial actions under the CERCLA process are implemented at the AOCs in order of priority as funding is available or unless other priorities surface, such as land use needs.

The purpose of this Phase I RI is to determine the nature and extent of contamination so that quantitative human health and ecological risk assessments can be performed. Depending on the outcome of the risk assessments, an AOC will either require no further action (NFA) or will be the subject of further investigations, including a Phase II RI and a feasibility study (FS), to evaluate potential remedies and future actions.

The scope of this investigation is to complete the assessment of the extent of contamination and to complete a human health risk assessment (HHRA) and ecological risk assessment (ERA) for the purpose of reaching a remedial action decision. The primary objectives of the Phase I RI are as follows:

- Abandonment of existing monitoring wells MW-1, -2, -3, -4, and -5.

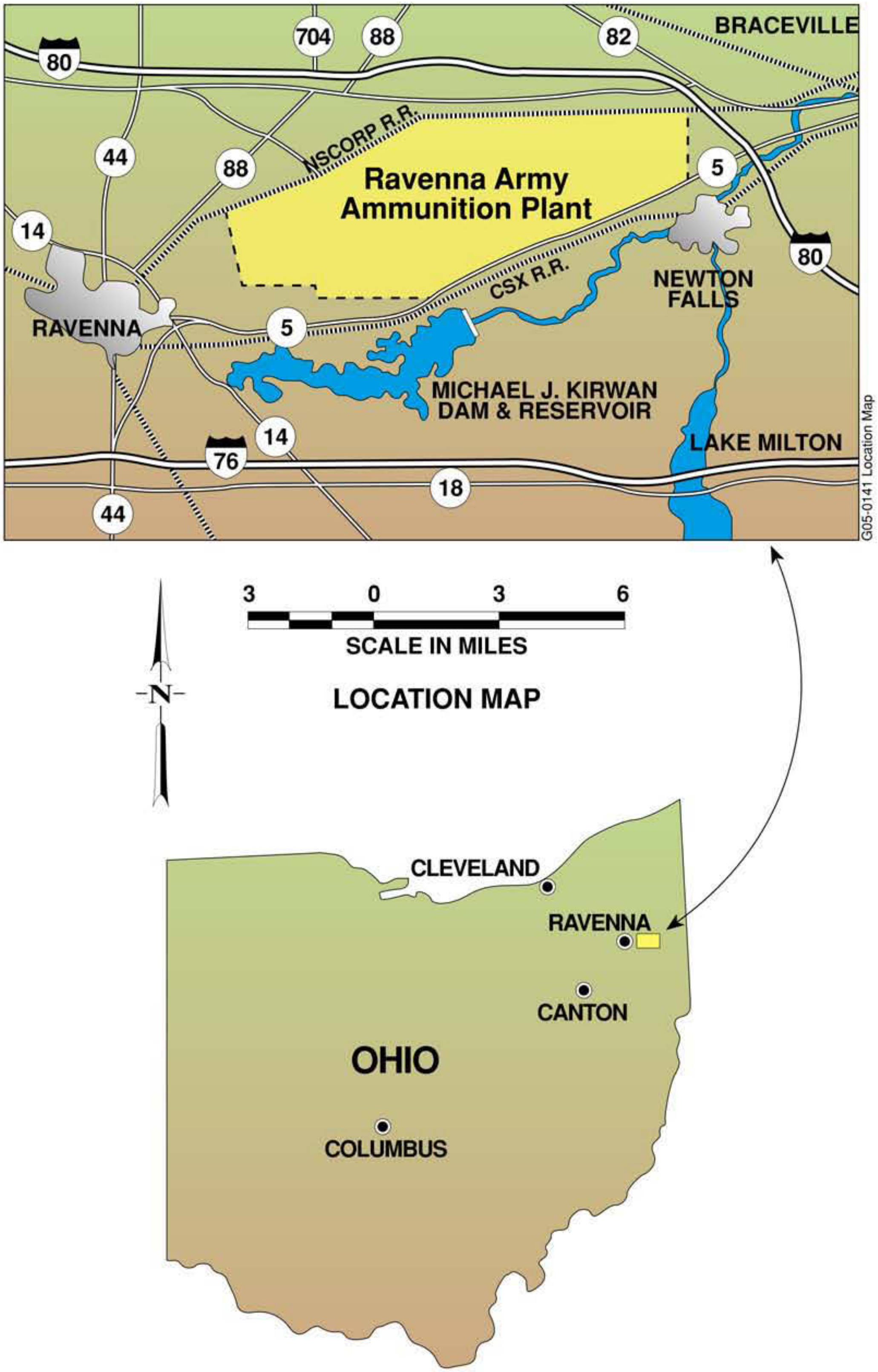
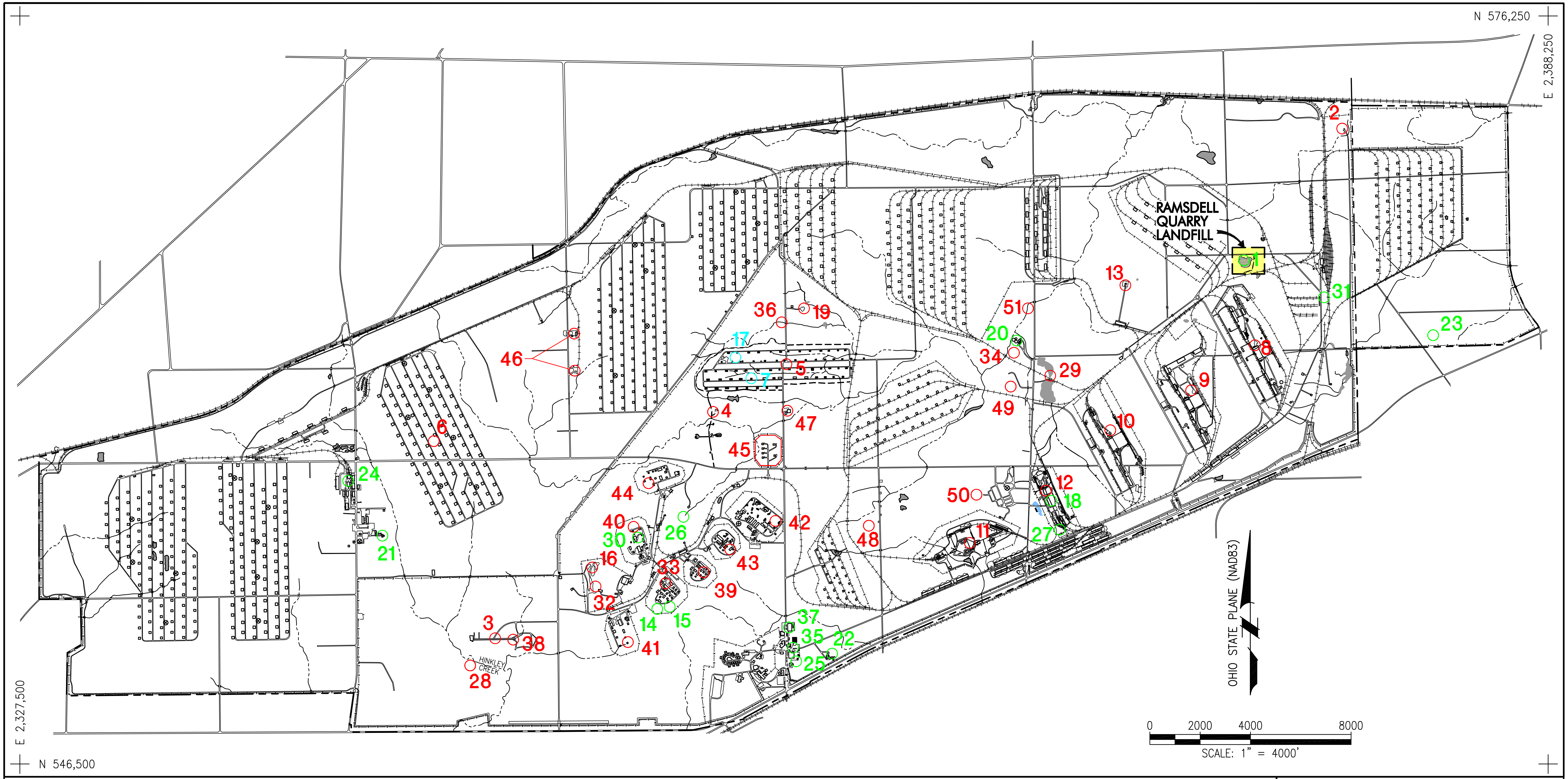


Figure 1-1. General Location and Orientation of RVAAP



LEGEND:

1	RAMSDELL QUARRY LANDFILL
2	ERIE BURNING GROUNDS
3	DEMOLITIONS AREA #1
4	DEMOLITIONS AREA #2
5	WINKLEPECK BURNING GROUNDS
6	C BLOCK QUARRY
7	BUILDING 1601 HAZARDOUS WASTE STORAGE
8	LOAD LINE 1 AND DILUTION/SETTLING POND
9	LOAD LINE 2 AND DILUTION/SETTLING POND
10	LOAD LINE 3 AND DILUTION/SETTLING POND
11	LOAD LINE 4 AND DILUTION/SETTLING POND
12	LOAD LINE 12 AND DILUTION/SETTLING POND
13	BUILDING 1200 AND DILUTION/SETTLING POND
14	LOAD LINE 6, EVAPORATION UNIT
15	LOAD LINE 6, TREATMENT PLANT
16	QUARRY LANDFILL/FORMER FUZE & BOOSTER BURNING PITS
17	DEACTIVATION FURNACE
18	LOAD LINE 12 PINK WASTE WATER TREATMENT
19	LANDFILL NORTH OF WINKLEPECK BURNING GROUND
20	SAND CREEK SEWAGE TREATMENT PLANT
21	DEPOT SEWAGE TREATMENT PLANT
22	GEORGE ROAD SEWAGE TREATMENT PLANT
23	UNIT TRAINING SITE WASTE OIL TANK
24	RESERVE UNIT MAINTENANCE AREA WASTE OIL TANK
25	BUILDING 1034 MOTOR POOL WASTE OIL TANK
26	FUZE BOOSTER AREA SETTLING TANKS
27	BUILDING 854-PCB STORAGE
28	MUSTARD AGENT BURIAL SITE
29	UPPER AND LOWER COBB'S POND COMPLEX
30	LOAD LINE 7 PINK WASTEWATER TREATMENT PLANT
31	ORE PILE RETENTION POND
32	40- AND 60-MM FIRING RANGE
33	FIRESTONE TEST FACILITY
34	SAND CREEK DISPOSAL ROAD LANDFILL
35	1037 BUILDING-LAUNDRY WASTEWATER SUMP
36	PISTOL RANGE
37	PESTICIDE STORAGE BUILDING T-4452
38	NACA TEST AREA
39	LOAD LINE 5/FUZE LINE 1
40	LOAD LINE 7/BOOSTER LINE 1
41	LOAD LINE 8/BOOSTER LINE 2
42	LOAD LINE 9/DETONATOR LINE
43	LOAD LINE 10/PERCUSSION ELEMENT
44	LOAD LINE 11/ARTILLERY PRIMER
45	WET STORAGE AREA
46	BUILDINGS F-15 AND F-16
47	BUILDING T-5301 DECONTAMINATION
48	ANCHOR TEST AREA
49	CENTRAL BURN PITS
50	ATLAS SCRAP YARD
51	DUMP ALONG PARIS-WINDHAM ROAD
○	CERCLA
○	RCRA
○	OTHER REGULATORY
┼┼┼┼┼┼┼┼┼	RAILROAD TRACKS
—x—x—	FENCELINE
— — —	PROPERTY BOUNDARY
～	STREAM OR CREEK

US Army Corps of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

RAVENNA ARMY AMMUNITION PLANT (RVAAP 2)
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
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Figure 1-2. Ravenna Army Ammunition Plant Facility Map

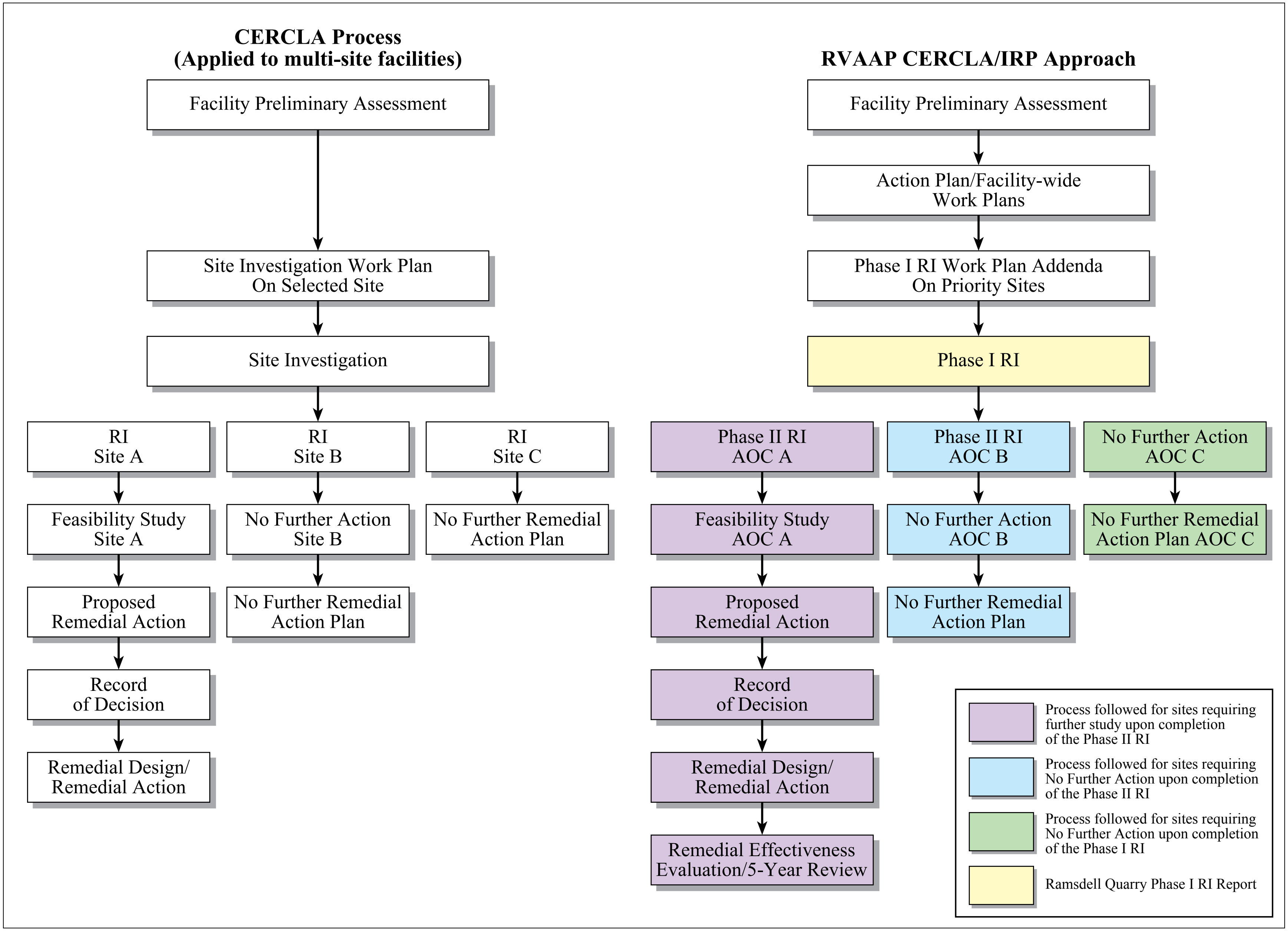

Figure 1-3. CERCLA Approach at RVAAP

- Install additional monitoring wells downgradient (north-northwest) of the AOC to bound the extent of contamination observed in groundwater adjacent to the quarry and to further evaluate potentiometric gradient reversal, observed previously adjacent to the quarry.

- Install additional monitoring wells upgradient (south-southeast) of the AOC to identify if any potential migration of contaminants from Load Line 1 is occurring, which might account for contaminants observed at RQL.

- Conduct multiple sampling rounds of newly installed wells under both base flow/dry conditions and high flow/storm event conditions to determine if storm-induced flushing and transport of contaminants is occurring.

- Utilize existing data (e.g., surface water, sediment, and groundwater) and surface soil data acquired under the Phase I RI to complete an HHRC in accordance with Ravenna facility-wide risk assessment guidance and an Ohio Level II ERA.

- Conduct surface soil sampling using multi-increment sampling techniques to evaluate the methodology, the feasibility of the method for characterizing AOCs, and the future application of this sampling technique at RVAAP.

- Update AOC site characteristics and refine the CSM using newly acquired Phase I RI data.

- Assess any remaining data gaps with respect to sources and extent of sediment, surface water, and groundwater contamination.

- Provide recommendations for any additional investigations and/or actions.

To meet the primary project objectives, investigation-specific data quality objectives (DQOs) were developed using the approach presented in the Facility-wide Sampling and Analysis Plan (SAP) (USACE 2001). The DQOs specific to the RQL Phase I RI are discussed in Section 1.3.4.

The investigation approach to the Phase I RI at RQL involved a combination of field and laboratory activities to characterize the AOC. Field investigation techniques included soil sampling using hand-sampling tools and installation of monitoring wells using air rotary methods and groundwater sampling. The field program was conducted in accordance with the Facility-wide SAP (USACE 2001a) and the *Sampling and Analysis Plan Addendum No. 1 for the Phase I Remedial Investigation of Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2003b).

1.2 GENERAL FACILITY DESCRIPTION

1.2.1 Historical Mission and Current Status

RVAAP is a 1,481-acre portion of the 21,419-acre Ravenna Training and Logistics Site (RTLS) of the Ohio Army National Guard (OHARNG). A total of 19,938 acres of the former 21,419-acre RVAAP was transferred to the United State Property and Fiscal Officer for Ohio in 1996 and 1999 for use by OHARNG as a military training site. The current RVAAP consists of 1,481 acres in several distinct parcels scattered throughout the confines of the OHARNG RTLS. RVAAP and RTLS are co-located on contiguous parcels of property and the RTLS perimeter fence encloses both installations. Because the IRP encompasses past activities over the entire 21,419 acres of the former RVAAP, the site description of RVAAP includes the combined RTLS and RVAAP properties. RVAAP was previously operated as a government-owned, contractor-operated U. S. Army facility. Currently, the Installation is jointly operated by the U. S. Army Rock Island BRAC Field Office and OHARNG.

RVAAP is located within the confines of RTLS, which is in northeastern Ohio within Portage and Trumbull counties, approximately 4.8 km (3 miles) east northeast of the town of Ravenna and approximately 1.6 km (1 mile) northwest of the town of Newton Falls. RVAAP portions of the Installation are solely located within Portage County. The Installation consists of a 17.7-km (11-mile) long, 5.6-km (3.5-mile)-wide tract bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad on the south; Garrett, McCormick, and Berry roads on the west; State Route 534 to the east, and the Norfolk Southern Railroad on the north (see Figures 1-1 and 1-2). The Installation is surrounded by several communities: Windham on the north, Garrettsville 9.6 km (6 miles) to the northwest, Newton Falls 1.6 km (1 mile) to the east, Charlestown to the southwest, and Wayland 4.8 km (3 miles) southeast.

Industrial operations at RVAAP consisted of 12 munitions-assembly facilities referred to as “load lines.” Load Lines 1 through 4 were used to melt and load 2,4,6-trinitrotoluene (2,4,6-TNT) and Composition B into large-caliber shells and bombs. The operations on the load lines produced explosive dust, spills, and vapors that collected on the floors and walls of each building. Periodically, the floors and walls were cleaned with water and steam. The liquid, containing 2,4,6-TNT and Composition B, was known as “pink water” for its characteristic color. Pink water was collected in concrete holding tanks, filtered, and pumped into unlined ditches for transport to earthen settling ponds. Load Lines 5 through 11 were used to manufacture fuzes, primers, and boosters. Potential contaminants in these load lines include lead compounds, mercury compounds, and explosives. From 1946 to 1949, Load Line 12 was used to produce ammonium nitrate for explosives and fertilizers prior to its use as a weapons demilitarization facility.

In 1950, the facility was placed in standby status and operations were limited to renovation, demilitarization, and normal maintenance of equipment, along with storage of munitions. Production activities were resumed during the Korean Conflict (July 1954 to October 1957) and again during the Vietnam Conflict (May 1968 to August 1972). In addition to production missions, various demilitarization activities were conducted at facilities constructed at Load Lines 1, 2, 3, and 12. Demilitarization activities included disassembly of munitions, explosives melt-out, and recovery operations using hot water and steam processes. Periodic demilitarization of various munitions continued through 1992.

In addition to production and demilitarization activities at the load lines, other facilities at RVAAP include sites that were used for the burning, demolition, and testing of munitions. These burning and demolition grounds consist of large parcels of open space or abandoned quarries. Potential contaminants at these AOCs include explosives, propellants, metals, waste oils, and sanitary waste. Other types of AOCs present at RVAAP include landfills, an aircraft fuel tank testing facility, and various general industrial support and maintenance facilities.

1.2.2 Demography and Land Use

Population statistics from the 2000 Census state that the total populations of Portage and Trumbull Counties are 152,061 and 225,116, respectively. Population centers closest to RVAAP are Ravenna, with a population of 11,771, and Newton Falls, with a population of 5,002. The RVAAP facility is located in a rural area and is not close to any major industrial or developed areas. Approximately 55% of Portage County, in which the majority of RVAAP is located, consists of either woodland or farmland acreage. The Michael J. Kirwan Reservoir (also known as West Branch Reservoir) is the closest major recreational area and is located adjacent to the western half of RVAAP, south of State Route 5.

Until May 1999, about 364 ha (900 acres) of land and some existing facilities at RVAAP were used by the National Guard Bureau (NGB) for training purposes administered by OHARNG. Training and related activities, managed under the RTLS, included field operations and bivouac training, convoy training, equipment maintenance, and storage of heavy equipment. In a Memorandum of Agreement (MOA) dated December 1998, 6,544 ha (16,164 acres) of land was transferred from the Army JMC to NGB, effective May 1999, for expanded training missions. On May 13, 2002, an additional 3,774 acres of land was transferred from JMC to NGB via an amendment to the MOA. Approximately 1,481 acres of property remain under the control of RVAAP; this acreage includes AOCs and active mission areas (Figure 1-4). As AOCs are remediated, transfer of the remaining acreage to NGB will occur. OHARNG has prepared a comprehensive Environmental Assessment and an Integrated Natural Resources Management Plan, which addresses future uses of the property. These uses include hand grenade practice and qualification ranges, a light demolition range, and armored vehicle maneuver areas. Additional field support and cantonment facilities will be constructed to support future training.

1.3 RAMSDELL QUARRY LANDFILL SITE DESCRIPTION

A detailed history of process operations and waste processes for the original 38 identified AOCs at RVAAP, including RQL, is presented in the *Preliminary Assessment for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 1996). The following is a summary of the history and related contaminants for RQL.

1.3.1 Operational History

Ramsdell Quarry, designated as AOC RVAAP-01, is located in the northeastern portion of RVAAP and encompasses about 14 acres (Figure 1-2). The quarry was excavated about 9 to 12 m (30 to 40 ft) below existing grade into the Sharon Member of the Pottsville Formation. The original unconsolidated glacial material overlying the sandstone was only a few meters (< 10 ft) thick and appears to have been entirely removed. The excavated material, consisting of sandstone and quartz pebble conglomerate, was used for road and construction ballast. Quarry operations were discontinued in about 1941.

The western and southern portion of the abandoned quarry was subsequently used for landfill operations (RQL) between 1941 and 1989 (Figure 1-5). No information is available regarding landfill disposal activities between 1941 and 1976. From 1976 until the landfill was closed in 1989, only non-hazardous solid waste was deposited in RQL. In 1978, a portion of the abandoned quarry was permitted as a sanitary landfill by the state of Ohio. The permit required a 30-m (100-ft) buffer be maintained between the landfill and the pond; the extent of the pond prior to this time is not known. Closure of the permitted sanitary landfill was completed in May 1990 under state of Ohio solid waste regulations [Ohio Administrative Code (OAC) 3745-27-10]. Based on available information, the RQL cap on the former permitted landfill covers approximately 4 of the 14 acres comprising the RQL AOC. A requirement of closure was installation and semiannual monitoring of five monitoring wells (MW-1 through -5; Figure 1-5).

In addition, from 1946 to the 1950s, the bottom of the quarry was used to burn waste explosives from Load Line 1. Approximately 18,000 225-kg (500-lb) incendiary or napalm bombs were reported to have been burned in the abandoned quarry. Liquid residues from annealing operations were also dumped in the quarry. No additional historical information currently is available on how the quarry was used, other than for landfill operations, from the 1950s until 1976, when operational records show that non-hazardous solid wastes were placed in RQL.

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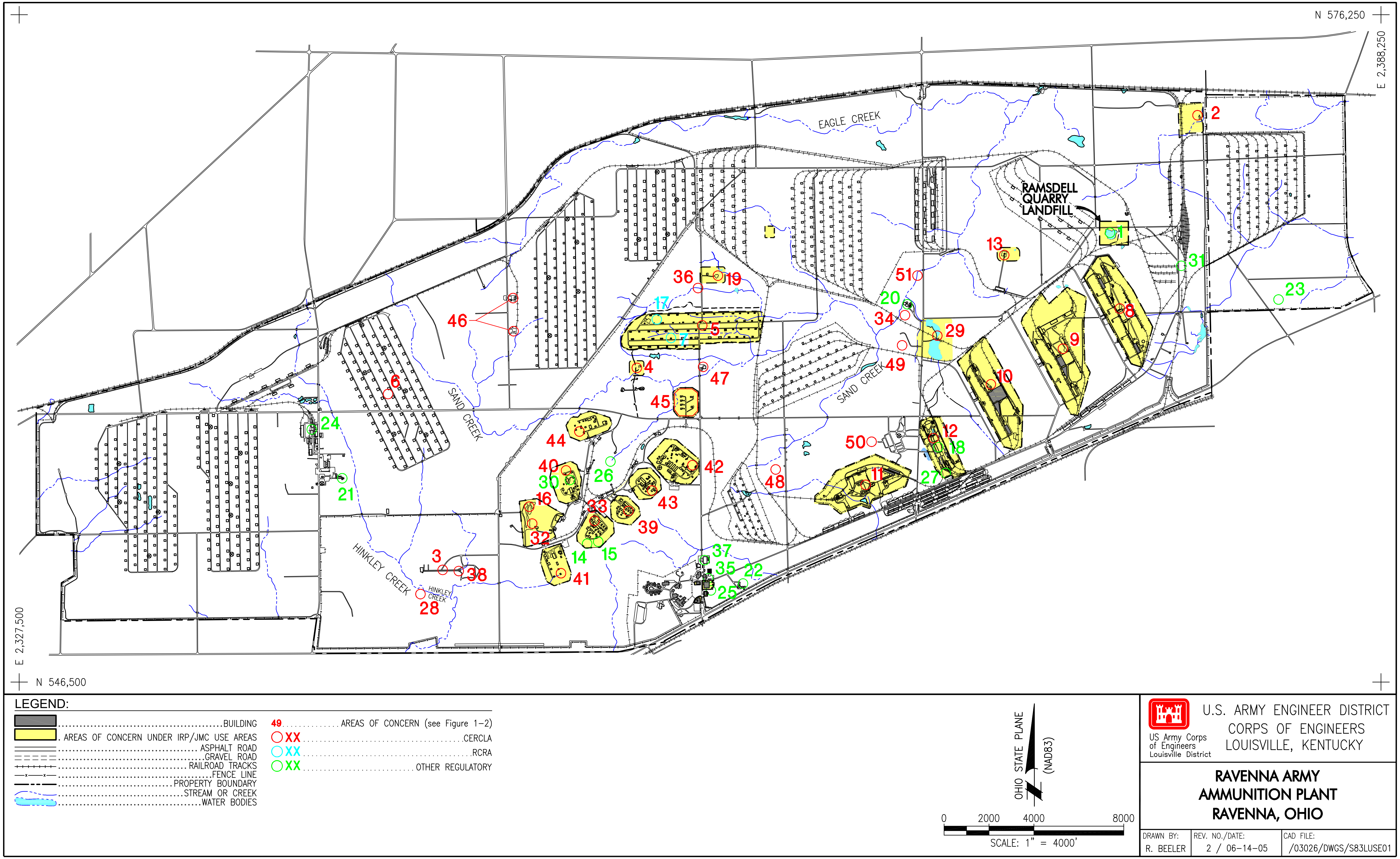

Figure 1-4. Current Land Use at RVAAP

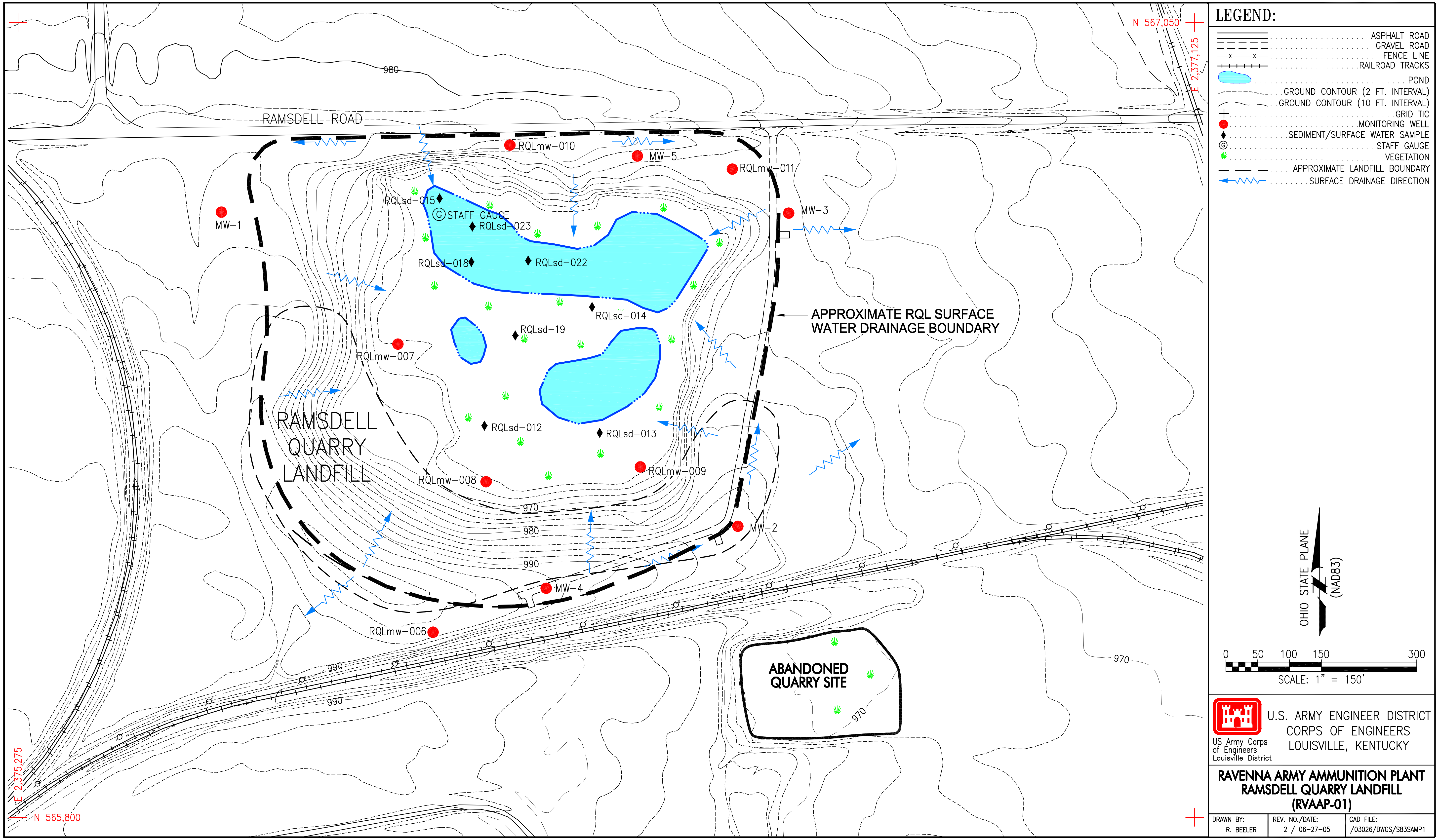

Figure 1-5. Ramsdell Quarry Landfill Site Map and Previous Sampling Locations

Based upon available information and past uses of the abandoned quarry, wastes may include domestic, commercial, and industrial solid and liquid wastes, including explosives [e.g., 2,4,6-TNT; hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); and Composition B], napalm, gasoline, acid dip liquor, annealing residue (e.g., sulfuric acid, shell casings, sodium orthosilicate, chromic acid, and alkali), aluminum chloride, and inert material. Interviews with former RVAAP personnel have indicated that much of the landfilled wastes and debris at the abandoned quarry were removed in the 1980s.

A much smaller quarry (also abandoned) was located directly southeast of RQL (Figure 1-5). Although no standing water was observed in the smaller quarry during earlier investigations, it was water filled in late August as a result of above average rainfall during the summer of 2003. No documentation of waste disposal or treatment exists for this quarry.

1.3.2 Previous Investigations at the Ramsdell Quarry Landfill

Previous investigations at RQL include monitoring related to post-closure and a Groundwater Investigation to evaluate the suitability of the post-closure groundwater-monitoring network and to investigate general groundwater/surface water interactions in the quarry. The Groundwater Investigation was designed to: (1) evaluate whether the closed landfill is in compliance with Ohio solid waste post-closure requirements, (2) to close data gaps in the RQL post-closure monitoring program, and (3) to address potential impacts upon groundwater related to historical operations at Ramsdell Quarry prior to use of the site for landfill operations. To achieve the project DQO, two phases (initial and follow-on) of work were conducted. A summary of the post-closure monitoring program results through 1999 and results of the Groundwater Investigation are contained in the Initial Phase Groundwater Investigation Report (USACE 1999) and the Final Phase Groundwater Investigation Report (USACE 2000).

The initial phase, conducted in July 1998, involved: (1) the installation and sampling of six new monitoring wells, (2) sampling of the existing RQL post-closure monitoring well system, (3) sampling of sediment and surface water within the quarry; and (4) construction of a staff gauge within the main quarry pond.

The follow-on phase of the investigation, which extended until July 15, 1999, included: (1) quarterly, dry season and wet season (storm event) sampling of the new monitoring well network and quarry pond surface water; (2) collection of long-term water levels from the new monitoring well network and quarry pond; (3) monthly manual water level measurements from all wells and the pond staff gauge; and (4) collection of precipitation data.

Future post-closure monitoring requirements were transferred to the Facility-Wide Groundwater Monitoring Plan when the Director’s Final Findings and Orders was issued on June 10, 2004. Under these orders, groundwater monitoring at RQL will continue for a minimum of 3 years following completion of all environmental investigations at the facility (Ohio EPA 2004).

Groundwater

Groundwater samples from the Groundwater Investigation contained low, but consistently detectable, concentrations of nine explosive compounds and associated degradation products and nitroglycerin. Multiple trace metals were present above facility-wide background criteria, as well as Ohio drinking water standards in both unfiltered and filtered samples. The most prevalent of these were aluminum, arsenic, cobalt, manganese, mercury, nickel, and zinc. Sporadic detections of bis(2-ethylhexyl)phthalate and volatile organic compounds (VOCs) were noted. Toluene and methylene chloride were the most persistent VOCs detected. No VOC results exceeded Ohio primary drinking water maximum contaminant levels (MCLs). The upgradient well (RQLmw-006) and two wells (RQLmw-007 and -008) located at the toe of the landfill typically had the highest percentages of detected contaminants. The furthest downgradient well (RQLmw-011) also had a comparatively high frequency of metals above background criteria.

Potentiometric data collected during the period of the investigation showed that horizontal potentiometric gradients are consistently to the northeast across the site during dry periods of the year. During these periods, the quarry pond often dries up and may even function as a sink through evapotranspiration processes. During the wet season of the year, a sufficient reservoir of water often exists in the quarry pond to act as a recharge point to groundwater. As a result, potentiometric surface elevations in upgradient well RQLmw-006 and those at the toe of the landfill are essentially equal. Rainfall events during the wet period of the year provide additional volume to the quarry pond and produce sufficient hydraulic head to produce slight, localized flow gradient reversals between the pond and well RQLmw-006 for short periods of time. Wells RQLmw-010 and -011 remain consistently downgradient of RQL throughout the year.

The distributions of contaminants in wells at RQL are consistent with the observed hydraulic characteristics. Considering that the horizontal potentiometric gradient during the wet season is flat and exhibits short-term reversals, RQL is the likely source of observed contaminants in well RQLmw-006. For a majority of the year, groundwater flow is consistently to the north-northeast providing the mechanism for contaminant migration to wells located at the toe of RQL and to RQLmw-011.

Sediment

Multiple metals and cyanide were detected in initial phase sediment samples in excess of facility-wide background criteria. Numerous semivolatile organic compounds (SVOCs), primarily polynuclear aromatic hydrocarbons (PAHs), were also detected. Volatile constituents were sporadic and limited to estimated concentrations of acetone, 2-butanone, and methylene chloride below reporting limits. Seven explosive compounds were detected at low concentrations in at least one sample. The most persistent of these were 2,4,6-TNT (three detects) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) with eight detects. Nitrocellulose was detected in three samples.

Surface Water

Arsenic, chromium, copper, lead, manganese, mercury, and zinc concentrations in surface water exceeded facility-wide surface water background criteria on at least two occasions. Iron and manganese exceed their respective Ohio state-wide surface water quality criteria (WQC); however, background values for these constituents exceed these criteria. Metals detected above background occurred primarily in the dry season when quarry pond water levels were extremely low, which likely produced evaporative concentration of dissolved constituents. Explosives were detected only on one occasion and propellants were not detected. Acetone, methylene chloride, and tetrachloroethene were each detected on one occasion. No SVOCs were detected.

1.3.3 Chemicals of Potential Concern

Based on available process knowledge and previous investigation results, the primary sources of contamination at RQL are metals from the landfill operations and explosives residues from the open burning of explosives. Operational data suggest that the primary chemicals of potential concern (COPCs) in groundwater may include the metals arsenic, iron, and manganese, which exceeded U. S. Environmental Protection Agency (EPA) Region 9 tap water preliminary remediation goals (PRGs). Also detected were benzene and bis(2-ethylhexyl) phthalate, with four detects. The explosive HMX was found in eight sediment samples with a maximum concentration of 0.14 mg/kg. Seventeen metals in sediment exceeded their background criteria, but those that were grossly elevated included arsenic, chromium, iron, lead, and magnesium. Cyanide was detected once in sediment at 2.8 mg/kg. Arsenic, iron, lead, and manganese all exceeded PRGs in surface water. In addition, the explosive 4-nitrotoluene was detected once at a concentration of 0.24 µg/L.

1.3.4 Ramsdell Quarry Landfill Phase I Remedial Investigation Data Quality Objectives

The facility-wide CSM, operational information, historical data and records, and data collected during the RQL Groundwater Investigation were used to design the Phase I RI sampling effort using the DQO approach presented in the Facility-wide SAP (USACE 2001). The DQOs for the Phase I RI were presented in detail in the Phase I RI SAP Addendum No. 1 (USACE 2003b). A summary of DQOs is presented below for reference purposes.

- **Groundwater.** Monitoring wells were installed to define the maximum downgradient (north-northeast) extent of contaminants associated with RQL. Three groundwater monitoring wells were installed in a configuration along the north side of Ramsdell Road that will provide data on general hydrogeologic characteristics and groundwater flow patterns. One monitoring well was installed to the west of RQL to fill a data gap in this portion of the AOC. One monitoring well was also installed southwest of the quarry to fill a data gap in this portion of the AOC and to monitor for potential northward contaminant transport from Load Line 1. One monitoring well was installed due south of the AOC, between RQL and Load Line 1; this location was selected to determine whether contaminants observed in the upgradient well at RQL (RQLmw-006) are sourced from Load Line 1.

- **Surface Soil.** Surface soil sampling employed a combination of discrete and multi-increment sampling to provide general characterization of the quarry bottom, as well as suspected contaminant accumulation points. Samples from 0.0 to 0.3 m (0 to 1 ft) were collected from ten discrete stations during the Phase I RI to: (1) assess contaminant occurrence and distribution, if any, in surface soil within the bottom of the quarry; and (2) undergo geotechnical analysis for total organic carbon. All discrete samples were analyzed for explosives, target analyte list (TAL) metals, cyanide, and SVOCs; two discrete samples were analyzed for propellants; and one discrete sample was analyzed for VOCs and pesticides/polychlorinated biphenyls (PCBs). Discrete soil sample stations were located to provide coverage in areas where dry sediment samples were not collected during the Groundwater Investigation. Ramsdell Quarry and Erie Burning Grounds represent the first application of multi-increment sampling at RVAAP. Discrete samples were collected for determination of the nature and extent of contamination, and for use in the risk assessments. The multi-increment sampling was conducted for the evaluation and advancement of the method only, which is why these data were not used in the risk assessments. In subsequent investigations, the emphasis may be shifted to the population mean achieved through multi-imcrement sampling, as the contaminant population mean transfers to reasonable maximum exposure for contaminant risk characterization. All multi-increment samples were analyzed for explosives TAL metals, cyanide, and SVOCs, and one multi-increment sample was also analyzed for propellants and pesticides/PCBs. For the purpose of multi-increment sampling, the bottom of Ramsdell Quarry, exclusive of the pond and landfill toe slope, was divided into approximately five equal areas (Figure 3-1). One multi-increment sample (comprised of at least 30 aliquots) was collected from each of the five separate areas. Each of the areas also contained discrete sample locations, and results of the discrete samples collected within each area are evaluated against the results of the multi-increment composite for each area in this report.

- **Sediment.** Sediment samples were not collected during the Phase I RI.

- **Surface Water.** Surface water samples were not collected during the Phase I RI.

1.4 REPORT ORGANIZATION

This Phase I RI Report is organized to meet Ohio EPA requirements in accordance with EPA, CERCLA Superfund process, and USACE guidance. The report consists of an Executive Summary, Chapters 1.0 through 10.0, and supporting appendices. Chapter 1.0 describes the purpose, objectives, and organization of this report and provides a description and history of RQL. Chapter 2.0 describes the environmental setting at RVAAP and Ramsdell Quarry, including the geology, hydrogeology, climate, population, and ecological resources. Chapter 3.0 describes the specific Phase I methods used for field data collection and the approach to analytical data management and laboratory programs. Chapter 4.0 presents the data generated during the Phase I RI and discusses the occurrence and distribution of contamination at RQL. Chapter 5.0 provides contaminant fate and transport evaluation. Chapter 6.0 includes the methodology and results of the human health evaluation. Chapter 7.0 summarizes the ecological risk evaluation. Chapter 8.0 provides results and conclusions of this study. Chapter 9.0 presents the recommendations, and Chapter 10.0 provides a list of referenced documents used to support this Phase I RI.

Appendices (A through M) to this Phase I RI Report for RQL contain supporting data collected during the Phase I RI. These appendices consist of soil and sampling logs, monitoring well installation logs, groundwater development and sampling logs, slug test logs, quality assurance (QA) documentation, laboratory analytical data, an munitions and explosives of concern (MEC) avoidance report, investigation-derived waste management characterization reports, and supporting data for the HHRA and ERA.

2.0 ENVIRONMENTAL SETTING

This chapter describes the physical characteristics of RVAAP and RQL and the surrounding environment that are factors in understanding potential contaminant transport pathways, receptors, and exposure scenarios for human health and ecological risks. The geology, hydrology, climate, and ecological characteristics of RVAAP were originally presented in the Initial Phase Groundwater Investigation Report (USACE 1999). The preliminary CSM for RQL presented at the end of this section is refined and updated in Chapter 8.0 based on site-specific data from the Phase I RI and local and regional information.

2.1 RVAAP PHYSIOGRAPHIC SETTING

RVAAP is located within the Southern New York Section of the Appalachian Plateaus physiographic province (USGS 1968). This province is characterized by elevated uplands underlain primarily by Mississippian- and Pennsylvanian-age bedrock units that are horizontal or gently dipping. The province is characterized by its rolling topography with incised streams having dendritic drainage patterns. The Southern New York Section has been modified by glaciation, which rounded ridges and filled major valleys and blanketed many areas with glacially derived unconsolidated deposits (i.e., sand, gravel, and finer-grained outwash deposits). As a result of glacial activity in this section, old stream drainage patterns were disrupted in many locales, and extensive wetland areas developed.

2.2 SURFACE FEATURES AND SITE TOPOGRAPHY

RQL is located in the northeastern portion of RVAAP and encompasses about 5.7 ha (14 acres) (Figure 1-2). The quarry was excavated about 9 to 12 m (30 to 40 ft) below existing grade into the Sharon Member of the Pottsville Formation. The original unconsolidated glacial material overlying the sandstone was only a few feet (less than 10 ft) thick and appears to have been entirely removed.

Figure 2-1 depicts current site conditions at RQL at the time of the Phase I RI. Because of former quarry operations, the RQL surroundings are characterized by bedrock often exposed on the ground surface or thin soil cover. RQL is underlain by weathered, fractured, fine- to medium-grained orthoquartzite sandstone of the Sharon Member of the Pennsylvanian Pottsville Formation. Bedrock is thinly to medium-bedded with prevalent cross bedding. Topographic relief between the surface of the pond and the top of the closed landfill is about 13 m (40 ft), representing the former extent of quarrying in this area. The closed landfill is U-shaped and has a compacted-soil cover that is vegetated and appears to be intact.

The quarry pond is generally less than 1.3 m (4 ft) deep and is underlain by thin deposits of sediment over bedrock. The pond is intermittent and has been observed to be dry for extended periods. No perennial streams exist in the immediate vicinity of the site. Several drainage ways and ditch lines are located along access roads and the rail line; however, these contain water only during storm flow conditions. Overall drainage patterns in the immediate site vicinity are toward the quarry pond, which is the lowest point in the area. No surface water drainage out of the quarry pond occurs (see Figure 1-5).

Figure 2-1. Site Conditions at Ramsdell Quarry, November 2003 (view to the northwest)

2.3 SOILS AND GEOLOGY

2.3.1 Regional Geology

The regional geology at RVAAP consists of horizontal to gently dipping bedrock strata of Mississippian and Pennsylvanian age overlain by varying thicknesses of unconsolidated glacial deposits. The bedrock and unconsolidated geology at RVAAP and geology specific to RQL are presented in the following subsections.

2.3.1.1 Soils and glacial deposits

Bedrock at RVAAP is overlain by deposits of the Wisconsin-aged Lavery Till in the western portion of the facility and the younger Hiram Till and associated outwash deposits in the eastern portion (Figure 2-2) (ODNR 1982). Unconsolidated glacial deposits vary considerably in their character and thickness across RVAAP, from zero in some of the eastern portion of the facility to an estimated 46 m (150 ft) in the south-central portion.

Thin coverings of glacial materials have been completely removed as a consequence of human activities at locations such as RQL, and bedrock is present at or near the ground surface in many locations, such as Load Lines 1 and Line 2. Where these glacial materials are still present, their distribution and character indicate their origin in ground moraine. These tills consist of laterally discontinuous assemblages of yellow-brown, brown, and gray silty clays to clayey silts, with sand and rock fragments. Deposits from bodies of glacial-age standing water may also have been encountered, in the form of > 15-m (50-ft)-thick deposits of uniform light gray silt.

Soils at RVAAP are generally derived from the Wisconsin-age silty clay glacial till. Distributions of soil types are discussed and mapped in the Soil Survey of Portage County, Ohio (USDA 1978). Much of the native soil at RVAAP was reworked or removed during construction activities in operational areas of the installation. According to the Portage County soil survey, the major soil types found in the high-priority AOCs are silt or clay loams with permeabilities ranging from 6.0×10^{-7} to 1.4×10^{-3} cm/sec.

2.3.1.2 Bedrock stratigraphy

The bedrock encountered in studies of RVAAP includes formations of Mississippian and Pennsylvanian age, which dip to the south at a rate of approximately 5 to 10 ft/mile. The Mississippian Cuyahoga Group is present at depths of approximately 200 ft below ground surface (bgs) throughout the majority of the site. However, the Meadville Shale Member of the Cuyahoga Group is present at or near the surface in the very northeastern corner of RVAAP. The Meadville Shale is a blue-gray silty shale characterized by alternating thin beds of sandstone and siltstone.

The Sharon Member of the Pennsylvanian Pottsville Formation unconformably overlies the Meadville Shale Member of the Mississippian Cuyahoga Group. The unconformity has a relief of as much as 200 ft in Portage County, and this is reflected in the variation of thickness of the Sharon Member. The Sharon Member consists of two units: a shale and a conglomerate. The conglomerate unit of the Sharon Member (informally referred to as the Sharon Conglomerate) is a highly porous, permeable, cross-bedded, frequently fractured and weathered orthoquartzite sandstone, which is locally conglomeratic and exhibits an average thickness of 100 ft. The Sharon Conglomerate has a thickness of as much as 250 ft where it was deposited in a broad channel cut into Mississippian rocks. In marginal areas of the channel, the

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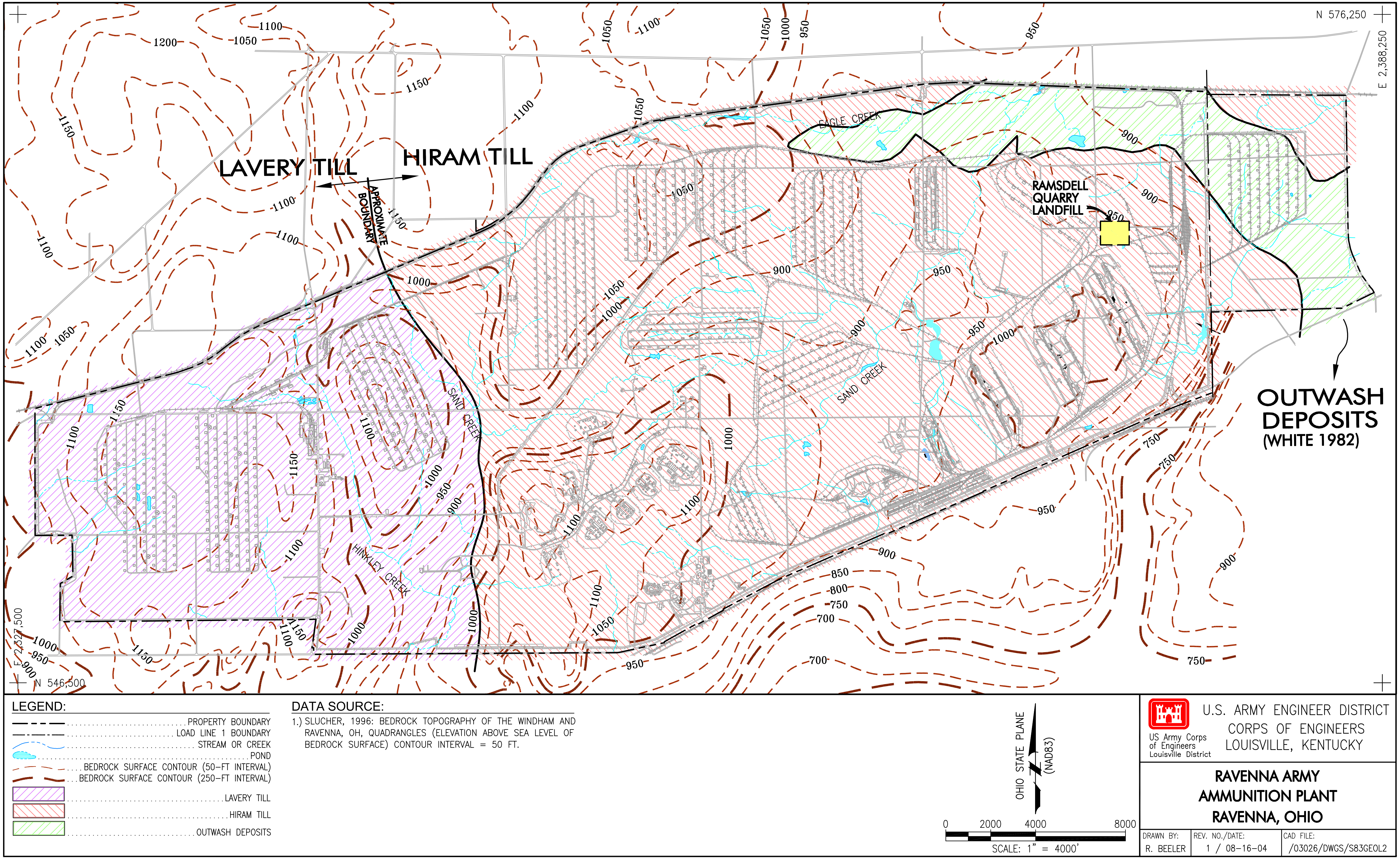

Figure 2-2. Geologic Map of Unconsolidated Deposits on RVAAP

conglomerate unit thins to about 20 ft and in places may be missing, owing to non-depostion on the uplands of the early Pennsylvanian erosional surface. Thin shale lenses occur sporadically within the upper part of the conglomerate unit.

The shale unit of the Sharon Member (informally referred to as the Sharon Shale) is a light to dark-gray fissile shale, which overlies the conglomerate in some locations, but has been eroded in most areas of RVAAP. The Sharon Member outcrops in many locations in the eastern half of RVAAP.

In the western half of RVAAP, the remaining members of the Pottsville Formation found in the local area overlie the Sharon Member. These remaining members of the Pottsville Formation are not found in the eastern half of the site either because the land surface was above the level of deposition or they were eroded. The Connoquenessing Sandstone Member, which unconformably overlies the Sharon Member, is a sporadic, relatively thin channel sandstone comprised of gray to white, coarse-grained quartz with a higher percentage of feldspar and clay than the Sharon Conglomerate. The Mercer Member is found above the Connoquenessing Sandstone and consists of silty to carbonaceous shale with many thin and discontinuous lenses of sandstone in its upper part. The Homewood Sandstone Member unconformably overlies the Mercer and is the uppermost unit of the Pottsville Formation. The Homewood occurs as a caprock on bedrock highs in the subsurface and ranges from a well-sorted, coarse-grained, white quartz sandstone to a tan, poorly sorted, clay-bonded, micaceous, medium- to fine-grained sandstone.

2.3.2 Geologic Setting of the Ramsdell Quarry Landfill

2.3.2.1 Soils

As a former rock quarry, the RQL surroundings are characterized by bedrock exposed on the ground surface, with negligible natural soil cover.

2.3.2.2 Bedrock geology

RQL is underlain by weathered, fractured, fine- to medium-grained orthoquartzite sandstone of the Sharon Conglomerate unit of the Sharon Member (Pottsville Formation). The Sharon Member is a uniform, medium- to fine-grained, fractured sandstone across the site, with the exception of an occurrence of a more competent (unfractured), gray, poorly sorted sandstone with thinly bedded shale encountered at wells RQLmw-006 and -011. This lithology differs significantly from the surrounding quartz sandstone in that it contains a wider range of grain sizes and other non-quartz minerals. Thin bedding-plane laminations, consisting of finer-grained gray or black material, occur throughout the site ranging in orientation from horizontal to approximately 100 degrees from the core axis. Open, re-cemented, and highly weathered fractures are prevalent. Many fractures exhibit iron staining and iron oxy-hydroxide coatings (e.g., limonite). Fracturing occurs both parallel to and at oblique angles to bedding planes, as well as in massive zones. Weathering along fractures has been sufficient to completely break down the interstitial cement in some cases.

2.4 HYDROGEOLOGY

2.4.1 Regional Hydrogeology

Sand and gravel aquifers are present in the buried-valley and outwash deposits in Portage County, as described in the *Phase I Remedial Investigation Report for High-Priority Areas of Concern at RVAAP* (USACE 1998). Generally, these saturated zones are too thin and localized to provide large quantities of water for industrial or public water supplies; however, yields are sufficient for residential water supplies.

Lateral continuity of these aquifers is not known. Recharge of these units comes from surface water infiltration of precipitation and surface streams. Specific groundwater recharge and discharge areas at RVAAP have not been delineated. However, extensive upland areas, such as north of the Winklepeck Burning Grounds (WBG) and in the western portion of the facility, are presumed to be regional recharge zones. The major perennial surface water drainages (e.g., Sand Creek, Hinkley Creek, and Eagle Creek) are presumed to be the major groundwater discharge areas (Section 2.4.1.3).

2.4.1.1 Unconsolidated sediment

The thickness of the unconsolidated interval at RVAAP ranges from thin to absent in the southeastern portion of RVAAP to an estimated 45 m (150 ft) in the central portion of the installation. The groundwater table occurs within the unconsolidated zone in many areas of the installation. Because of the very heterogeneous nature of the unconsolidated glacial materials, groundwater flow patterns are difficult to determine with a high degree of accuracy. Vertical recharge from precipitation likely occurs via infiltration along root zones and desiccation cracks and partings within the soil column. Laterally, most groundwater flow likely occurs along preferential pathways (e.g., sand seams, channel deposits, or other stratigraphic discontinuities) having higher permeabilities than surrounding clay or silt-rich materials. Moderately high horizontal hydraulic conductivities have been measured in the unconsolidated materials underlying WBG. Hydraulic conductivities measured during the Phase II RI at WBG range from 3.87×10^{-2} to 5.65×10^{-4} cm/sec, which reflect a comparatively high percentage of sand-sized material in the unconsolidated zone in portions of this AOC. At Load Line 1, slug tests performed at three unconsolidated wells during the Phase I RI (USACE 1998) revealed conductivities of 6.5×10^{-5} to 1.7×10^{-3} cm/sec. Unconsolidated zone hydraulic conductivities at Load Lines 4 and 12 reflect the occurrence of much finer-grained materials (clays and silts) in this portion of RVAAP, with slug test results ranging from 2.32×10^{-3} to 2.35×10^{-6} cm/sec.

2.4.1.2 Bedrock hydrogeology

During the period of RVAAP operations, approximately 75 wells were drilled for potable and industrial uses. Of these, only 15 were considered adequate producers. As of 1978, only five wells were used continuously (USATHAMA 1978). The sandstone facies of the Sharon Member, and in particular the Sharon Conglomerate, were the primary sources of groundwater during RVAAP's active phase, although some wells were completed in the Sharon Shale. Past studies of the Sharon Sandstone indicate that the highest yields come from the quartzite-pebble conglomerate facies and from jointed and fractured zones. Where it is present, the overlying Sharon Shale acts as a relatively impermeable confining layer for the sandstone. Hydraulic conductivities in wells completed in the Sharon Shale generally are much lower than those in the sandstone.

2.4.1.3 Groundwater flow directions

A facility-wide water table map was constructed from data collected on August 27 and 28, 2001, as part of a facility-wide water level measurement and well inspection effort conducted under a separate project (USACE 2003a). Figure 2-3 illustrates the potentiometric surface across the eastern portion of RVAAP. Monitoring wells from which data were obtained are all screened within the uppermost groundwater interval at RVAAP, either at the water table or immediately below it. Both unconsolidated and bedrock zone wells are represented in the water level data set; thus, the potentiometric map presents a generalized representation of the water table surface. Perennial streams and ponds present at RVAAP were considered as expressions of the water table surface. Thus, to augment water level data in areas that did not have adequate well coverage, elevations of perennial streams and ponds, estimated from topographic base map

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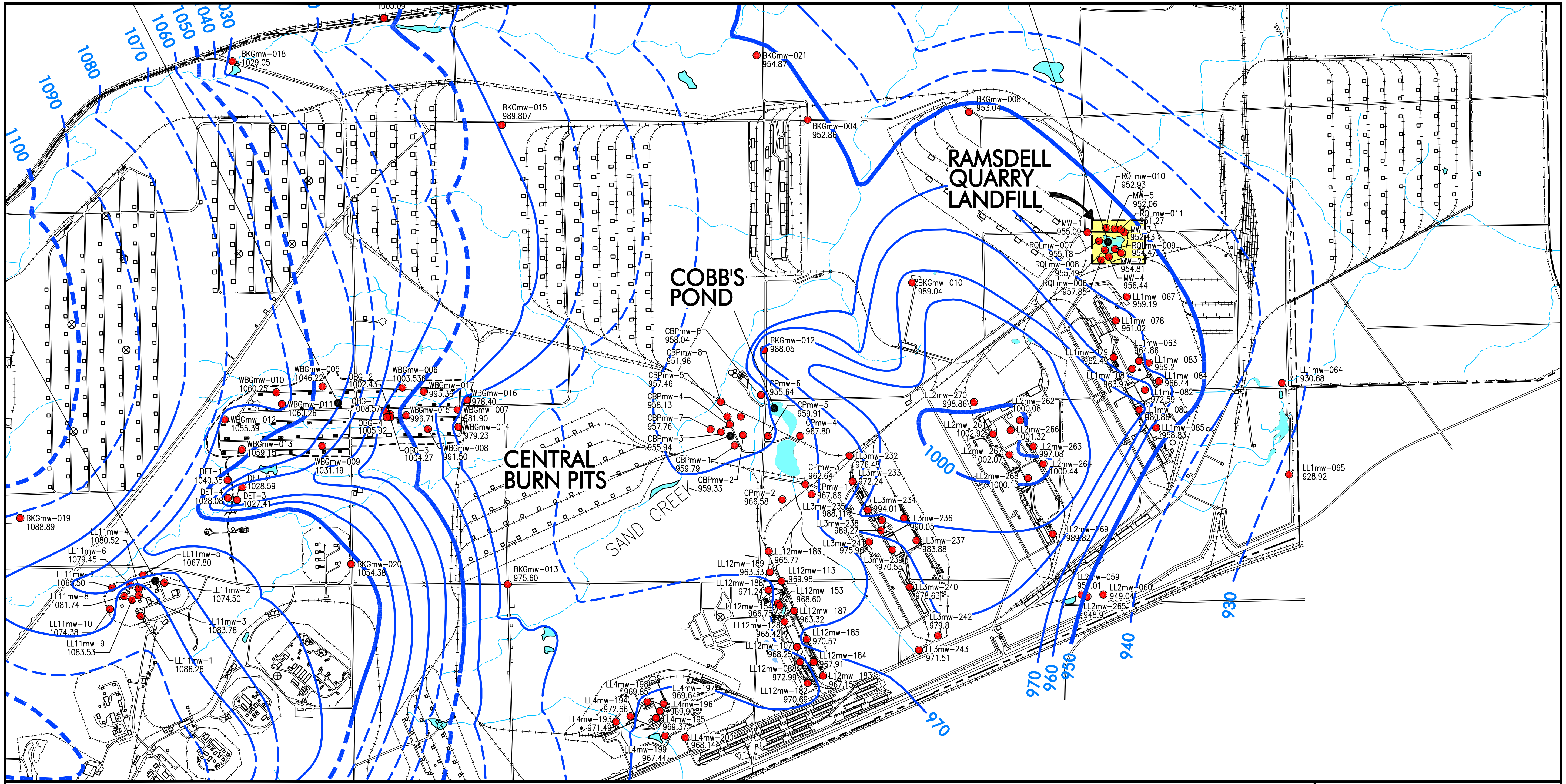

LEGEND:

- ▭ ....PRIMARY BUILDING
- ▭ ....SECONDARY BUILDING
- ....ASPHALT ROAD
- ....GRAVEL ROAD
- ....RAILROAD TRACKS
- ....FENCE LINE
- ....STREAM
- ....POND
- ● ....MONITORING WELL LOCATION
- ....RVAAP FACILITY BOUNDARY
- ............POTENTIOMETRIC SURFACE
- ....INFERRED POTENTIOMETRIC SURFACE
- 1093.79.........POTENTIOMETRIC SURFACE ELEVATION

NOTES:

1.) POTENTIOMETRIC MAP BASED ON FACILITY-WIDE WATER LEVEL MEASUREMENTS COLLECTED AUGUST 27/28, 2001. CONTOUR INTERVAL IS 10 FT.

2.) POTENTIOMETRIC SURFACE ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

US Army Corps
of Engineers
Louisville District

**RAVENNA ARMY
AMMUNITION PLANT
RAVENNA, OHIO**

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	1 / 08-16-04	/03026/DWGS/S83POTN01

Figure 2-3. Facility-wide Potentiometric Map, August 2001

files, were used to infer water table elevations. Topographic surface controls from base map files were also used to guide placement of water table isopleths.

The facility-wide potentiometric map shows that the water table surface is a subdued representation of the topography of the region. The predominant groundwater flow direction is to the east, with water table elevations decreasing from a high of about 346 m (1,136 ft) above mean sea level (amsl) in the northwest portion of the facility to a low of about 283 m (928 ft) amsl southeast of Load Line 1 (well LL1mw-065). A significant potentiometric high centered around Load Line 2 is indicated in the southeastern portion of RVAAP. This potentiometric high results in localized radial flow vectors in this portion of the facility. A groundwater divide is also inferred in the western portion of the facility based on surface stream and topographic elevations, although little potentiometric data exist in this region to confirm its presence.

At the watershed scale (i.e., Sand Creek, Hinkley Creek, South Fork of Eagle Creek), groundwater flow generally mirrors surface drainage patterns. Regional drainage patterns along Sand Creek in the northeast portion of RVAAP result in a localized perturbation in the overall flow direction to the north-northeast. In several locations along the southern boundary of RVAAP, south-southeast perturbations in the overall observed groundwater flow patterns are observed as follows:

- a localized south-southeasterly flow component from the potentiometric high area centered around Load Lines 1, 2, and 3 toward the facility boundary;
- a localized southerly flow component toward the facility boundary from the southernmost portion of Load Line 12;
- a localized southerly flow component toward the facility boundary from Load Line 4, which mirrors the direction of surface water flow in the unnamed tributary that drains this load line; and
- groundwater flow to the south in association with Hinkley Creek in the southwest portion of the site (i.e., NACA Test Area and Demolition Area 1 vicinity).

The potentiometric surface may be interpreted with a higher degree of confidence in the southeastern portion of RVAAP than in many other areas of the facility because of the density of monitoring wells present (i.e., vicinity of Cobb's Pond, Ramsdell Quarry, Load Lines 1 through 4, and Load Line 12). The potentiometric surface and water table gradients in the vicinity of Cobb's Pond, Load Line 12, and Load Line 4 are subdued when compared to other portions of RVAAP, and they appear to be influenced by the abundant large surface water features and wetlands present in these areas.

Greater uncertainty in interpretation of groundwater flow directions exists in the vicinity of Load Line 12 and Demolition Area 2. Potential subsurface geologic heterogeneities in the vicinity of Load Line 12 create a complex potentiometric surface that is difficult to interpret with existing data. An apparent narrow potentiometric low oriented in a north-south direction extends along the central portion of Load Line 12 from South Service Road towards Cobb's Pond. This potentiometric low was also evident from water table data collected during 2000 and may be a representation of some type of anisotropy.

In the vicinity of Demolition Area 2, steep potentiometric gradients are inferred based on data from wells that existed in the area as of August 2001. Additional monitoring wells were installed at this AOC in the fall of 2002 as part of a Phase II RI. Data from the new Demolition Area 2 wells need to be included in any subsequent assessment of facility-wide potentiometric elevations and may alter the interpretation of gradients in this area.

2.4.1.4 Surface water system

The entire RVAAP facility is situated within the Ohio River Basin, with the West Branch of the Mahoning River representing the major surface stream in the area. This stream flows adjacent to the western end of the facility, generally from north to south, before flowing into the M. J. Kirwan Reservoir that is located to the south of State Route 5. The West Branch flows out of the reservoir along the southern facility boundary before joining the Mahoning River east of RVAAP.

The western and northern portions of RVAAP are characterized by low hills and dendritic surface drainage. The eastern and southern portions are characterized by an undulating to moderately level surface, with less dissection by surface drainage. The facility is marked with marshy areas and flowing and intermittent streams, with headwaters located in the higher regions of the site. Three primary watercourses drain RVAAP: the South Fork of Eagle Creek, Sand Creek, and Hinkley Creek.

Sand Creek, with a drainage area of 36 km^2 (13.9 $miles^2$), flows generally northeast to its confluence with the South Fork of Eagle Creek. In turn, the South Fork of Eagle Creek then continues in a northerly direction for 7 km (2.7 miles) to its confluence with Eagle Creek. The drainage area of the South Fork of Eagle Creek is 67.9 km^2 (26.2 $miles^2$), including the area drained by Sand Creek. Hinkley Creek, with a drainage area of 28.5 km^2 (11.0 $miles^2$), flows in a southerly direction through the installation to its confluence with the West Branch of the Mahoning River south of the facility.

Approximately 50 ponds are scattered throughout the installation. Many were built within natural drainageways to function as settling ponds or basins for process effluent and runoff. Others are natural glacial depressions or result from beaver activity. All water bodies at RVAAP support an abundance of aquatic vegetation and fish. None of the ponds within the installation are used as water supply sources.

Storm water runoff is controlled primarily by natural drainage, except in facility operations areas where extensive storm sewer networks and surface ditches help to direct runoff to drainage ditches and settling ponds. In addition, the storm sewer and drainage ditch systems were one of the primary drainage mechanisms for process effluent during the period that production facilities were in operation.

2.4.2 Ramsdell Quarry Landfill Hydrologic/Hydrogeologic Setting

As described in Section 1.3.2, potentiometric data for RQL show that horizontal potentiometric gradients are consistently to the northeast during dry periods of the year. During the wet season of the year, a sufficient reservoir of water exists in the quarry pond to induce a downward vertical hydraulic gradient (recharge) and produce flat hydraulic gradients across the site (Figure 2-4). Rainfall events during the wet period of the year produce slight, localized flow gradient reversals between the pond and upgradient well RQLmw-006 for short periods of time.

Results of slug tests performed during the Initial Groundwater Investigation in July 1998 and the Phase I RI reveal moderately high horizontal hydraulic conductivities in the weathered and fractured sandstone units underlying RQL. Typical hydraulic conductivities for sandstones range from 10^{-3} to 10^{-8} cm/sec (Freeze and Cherry 1979). The wells at RQL generally show conductivities in the sandstone ranging from 10^{-2} to 10^{-4} cm/sec. Fracturing in the sandstone units undoubtedly contributes to the high observed conductivities in the monitoring wells at RQL.

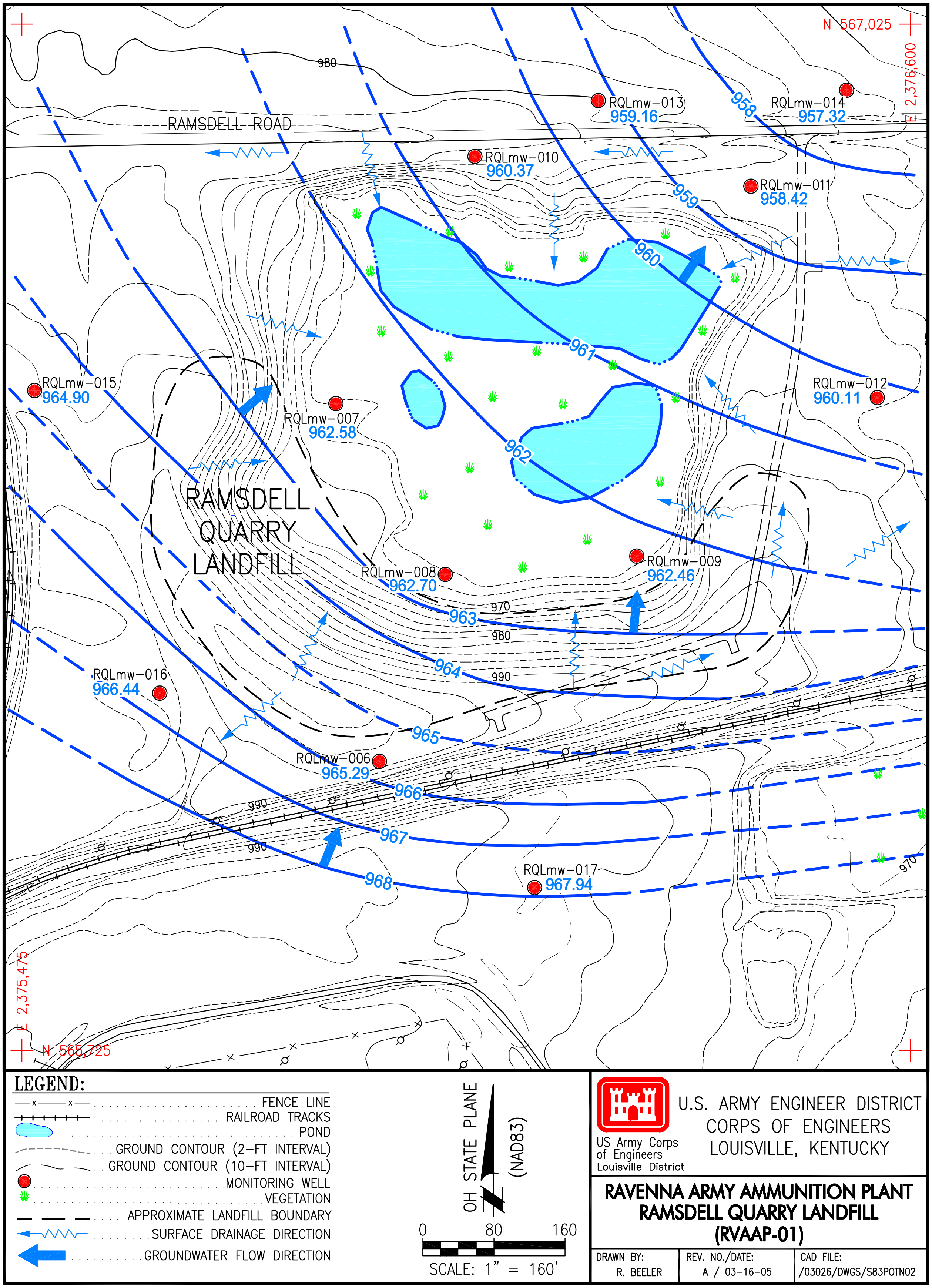

Figure 2-4. Ramsdell Quarry Potentiometric Surface, May 2004

2.5 CLIMATE

RVAAP has a humid continental climate characterized by warm, humid summers and cold winters. Precipitation varies widely through the year. The driest month is, on average, February, and the wettest month is July. Data from the National Weather Service compiled over the past 47 years indicated that the average rainfall for the area is 0.98 m (38.72 in.) annually. The average snowfall is 1.08 m (42.4 in.) annually. Severe weather, in the form of thunder and hail in summer and snowstorms in winter, is common. Tornadoes are infrequent in Portage County. The Phase I RI was conducted during the historically dry portion of the year, but overall climate conditions tended to be wetter than normal.

2.6 POTENTIAL RECEPTORS

2.6.1 Human Receptors

RVAAP consists of 8,668.3 ha (21,419 acres) and is located in northeastern Ohio, approximately 37 km (23 miles) east-northeast of Akron and 48.3 km (30 miles) west-northwest of Youngstown. RVAAP occupies east-central Portage County and southwestern Trumbull County. The 2000 Census lists the total populations of Portage and Trumbull counties at 152,061 and 225,116, respectively. Population centers closest to RVAAP are Ravenna, with a population of 11,771, and Newton Falls, with a population of 5,002. Approximately 55% of Portage County, in which the majority of RVAAP is located, consists of either woodland or farm acreage. The Michael J. Kirwan Reservoir (also known as West Branch Reservoir) is the closest major recreational area and is adjacent to the western half of RVAAP south of State Route 5.

The RVAAP facility is located in a rural area, is not accessible to the general public, and is not near any major industrial or developed areas. The facility is completely fenced and patrolled by security personnel. Army and full-time operating contractor staff (i.e., security, grounds and maintenance workers) are located on-site. Army and full-time operating contractor staff (e.g., security and grounds and maintenance workers) are located on-site. Additional subcontractor staff are on-site for varying periods of time, ranging from several weeks to more than 12 months, to complete specific demolition/decommissioning projects. Training activities under OHARNG involve an average of 4,500 personnel during the course of a month, who are on-site for periods of 3 days (inactive duty or weekend training) to 2 weeks (annual training).

Ramsdell Quarry is located in the eastern portion of RVAAP and is not currently used for OHARNG training activities. Groundskeeping activities are limited to regular mowing and infrequent brush clearing along Ramsdell Road on the north side of the AOC boundary. Six to 12 deer hunts take place at RVAAP during weekends each year in October and November. RQL is not currently included in the deer hunting program. Security activities consist of periodic surveillance along Ramsdell Road. Semiannual sampling of wells RQLmw-006 through -011 is performed in accordance with Ohio solid waste regulations. Potential future land uses for RQL and the immediate vicinity under the March 2003 OHARNG reuse program include security patrols and site maintenance. Additional information on future land uses is included in Chapter 6.0, Section 6.3.1.

2.6.2 Ecological Receptors

The dominant types of vegetative cover at RVAAP, including portions of Load Line 2 and its immediate surroundings, are forests and old fields of various ages. More than 60% of RVAAP is now in forest (Morgan 2004). Most of the old field cover is the result of earlier agricultural practices that left these sites with poor topsoil, which limits forest regeneration. Several thousand acres of agricultural fields were planted in trees during the 1950s and 1960s, but these plantings were not successful in areas with poor topsoil. Some fields, leased for cattle grazing during the same time period, were delayed in their reversion to forest. A few fields have been periodically mowed, maintaining them as old field, and 36 ha (90 acres) are leased as hay fields. RQL is covered with rough grasses and scrub vegetation within the former production area and forested areas in the non-production areas.

Forested wetlands, scrub-shrub wetlands, isolated wetlands, and wetlands associated with surface water features are abundant at RVAAP (OHARNG 2001). It is estimated that at least one-third to one-half of the property would meet the criteria for a jurisdictional wetland (OHARNG 2001). Jurisdictional wetland delineations are expensive and not practical for general planning purposes but can be done to support specific projects (OHARNG 2001). Various wetland maps are available for RVAAP, including the U. S. Fish and Wildlife Service National Wetlands Inventory Maps, USACE Waterways Experiment Station maps of primary wetland areas, and U. S. Geological Survey (USGS) identification of potential wetlands in Training Areas (OHARNG 2001). All of these maps are useful planning tools, but do not provide jurisdictional delineations suitable for compliance with Section 404 of the Clean Water Act (OHARNG 2001). There have been two jurisdictional delineations done in recent years to support National Environmental Protection Act requirements of specific project proposals (OHARNG 2001).

The wetland acreage identified on the NWI maps is unknown, but is much less than one-third to one-half of the installation acreage (OHARNG 2001). The USACE Water Experiment Station maps of primary wetland areas, as interpreted from aerial photographs of the installation, identify 1,917 acres of wetlands at RVAAP (OHARNG 2001). The mapped wetlands do not identify a lot of the forested and scrub-shrub wetland communities and do not fully encompass the extent of wetlands likely present at RVAAP (OHARNG 2001). There are 12 types of wetland communities present at RVAAP (OHARNG 2001).

Most of these wetlands exist because of poorly drained and hydric soils. Beaver impoundments contribute to wetland diversification in some parts of the site. A forested wetland area occurs in the western portion of the Load Line 2, and wetland areas exist along the tributary draining to Upper Cobb's Pond.

The flora and fauna at RVAAP are varied and widespread. No federal threatened or endangered or candidate threatened or endangered species have been observed on RVAAP. A list of state endangered, state threatened or potentially threatened, and state special interest species confirmed to be on RVAAP is provided in Table 2-1 (Morgan 2005). Additionally, five rare plant communities/significant natural areas have been identified on RVAAP, including the northern woods, Wadsworth Glen, Group 3 woods, B&O Wye Road area, and South Patrol Road swamp forest.

Restricted land use and sound forest management practices have preserved and enabled large forest tracts to mature. Habitat conversion at RVAAP, unlike most other habitat conversions occurring nationwide, has been toward restoration of the forests that covered the area prior to its being cleared for agriculture. The reversion of these agricultural fields to mature forest provides a diverse habitat from old field through several successional stages. Overall, the trend toward forest cover enhances the area for use by both plant and animal forest species. Future IRP activities will require consideration of these species to ensure that detrimental effects on threatened or endangered RVAAP flora and fauna do not occur; this will be discussed in the ERA (Chapter 7.0). There are no federal, state, or local parks or protected areas on RVAAP property.

Table 2-1. RVAAP Rare Species List as of 2005

RAVENNA TRAINING AND LOGISTICS SITE (RTLS)
RAVENNA ARMY AMMUNITION PLANT (RVAAP)
RARE SPECIES LIST
9 May 2005

I. Species confirmed to be on the RTLS/RVAAP property by biological inventories and confirmed sightings.

A. State Endangered

1. American bittern, *Botaurus lentiginosus* (migrant)
2. Northern harrier, *Circus cyaneus*
3. Yellow-bellied Sapsucker, *Sphyrapicus varius*
4. Golden-winged warbler, *Vermivora chrysoptera*
5. Osprey, *Pandion haliaetus* (migrant)
6. Trumpeter swan, *Cygnus buccinator* (migrant)
7. Mountain Brook Lamprey, *Ichthyomyzon greeleyi*
8. Graceful Underwing, *Catocala gracilis*
9. Ovate Spikerush, *Eleocharis ovata* (Blunt spike-rush)
10. Tufted Moisture-loving Moss, *Philonotis fontana* var. *caespitosa*
11. Bobcat, *Felis rufus*

B. State Threatened

1. Barn owl, *Tyto alba*
2. Dark-eyed junco, *Junco hyemalis* (migrant)
3. Hermit thrush, *Catharus guttatus* (migrant)
4. Least bittern, *Ixobrychus exilis*
5. Lest flycatcher, *Empidonax minimus*
6. *Psilotreta indecisa* (caddisfly)
7. Simple willow-herb, *Epilobium strictum*
8. Woodland Horsetail, *Equisetum sylvaticum*

C. State Potentially Threatened Plants

1. Pale sedge, *Carex pallescens*
2. Gray Birch, *Betula populifolia*
3. Butternut, *Juglans cinerea*
4. Northern rose azalea, *Rhododendron nudiflorum* var. *roseum*
5. Hobblebush, *Viburnum alnifolium*
6. Long Beech Fern, *Phegopteris connectilis*
7. Straw sedge, *Carex straminea*
8. Water avens, *Geum rivale*
9. Tall St. John's wort, *Hypercium majus*
10. Swamp oats, *Sphenopholis pensylvanica*
11. Shinning ladies'-tresses, *Spiranthes lucida*
12. Arbor Vitae, *Thuja occidentalis*
13. American Chestnut, *Castanea dentata*

Table 2-1. RVAAP Rare Species List as of 2005 (continued)

D. State Species of Concern

1. Pygmy shrew, *Sorex hovi*
2. Star-nosed mole, *Condylura cristata*
3. Woodland jumping mouse, *Napaeozapus insignis*
4. Sharp-shinned hawk, *Accipiter striatus*
5. Marsh wren, *Cistothorus palustris*
6. Henslow's sparrow, *Ammodramus henslowii*
7. Cerulean warbler, *Dendroica cerulea*
8. Prothonotary warbler, *Protonotaria citrea*
9. Bobolink, *Dolichonyx oryzivorus*
10. Northern bobwhite, *Colinus virginianus*
11. Common moorhen, *Gallinula chloropus*
12. Great egret, *Casmerodius albus*
13. Sora, *Porzana carolina*
14. Virginia Rail, *Rallus limicola*
15. Creek heelsplitter, *Lasmigona compressa*
16. Eastern box turtle, *Terrapene carolina*
17. Four-toed Salamander, *Hemidactylium scutatum*
18. *Stenonema ithica* (mayfly)
19. *Apamea mixta* (moth)
20. Brachylomia algens (moth)

E. State Special Interest

1. Canada warbler, *Wilsonia canadensis*
2. Little blue heron, *Egretta caerula*
3. Magnolia warbler, *Dendroica magnolia*
4. Northern waterthrush, *Seiurus noveboracensis*
5. Winter wren, *Troglodytes troglodytes*
6. Back-throated blue warbler, *Dendroica caerulescens*
7. Brown creeper, *Certhia americana*
8. Mourning warbler, *Oporornis philadelphia*
9. Pine siskin, *Carduelis pinus*
10. Purple finch, *Carpodacus purpureus*
11. Red-breasted nuthatch, *Sitta canadensis*
12. Golden-crowned kinglet, *Regulus satrapa*
13. Blackburnian warbler, *Dendroica fusca*
14. Blue grosbeak, *Guiraca caerulea*
15. Common snipe, *Gallinago gallinago*
16. American wigeon, *Anas americana*
17. Gadwall, *Anas strepera*
18. Green-winged teal, *Anas crecca*
19. Northern shoveler, *Anas clypeata*
20. Redhead duck, *Aythya americana*
21. Ruddy duck, *Oxyura jamaicensis*
22. *Pohlia elongata* var. *elongata* (No Common Name, Bryophyte)

Table 2-1. RVAAP Rare Species List as of 2005 (continued)

F. Rare Plant Communities/Significant Natural Areas

1. The area known as the northern woods contains Beech-sugar maple forest, oak-maple swamp forest, mixed swamp forest, oak-maple-tulip forest, oak-hickory forest, mixed floodplain forest, and successional woods, floating-leaved marsh, submergent marsh, emergent marsh, cat-tail marsh, sedge-grass meadow, mixed shrub swamp, buttonbush swamp, shrub bog, wet fields, ponds, and disturbed wetlands. This area is approximately 1,500 acres and includes a Pin Oak-Swamp White Oak-Red Maple (Northern Pin Oak) Flatwoods Forest. This community is ranked as a G2 community. This means that it is "imperiled globally because rarity (6 to 20 occurrences or few remaining individuals) or because of some factor(s) making it very vulnerable to extinction throughout its range." According to Dr. Barbara Andreas, who did the RTLS plant communities inventory, the best examples of this community in northeast Ohio are at RTLS. This area also contains good examples of Beech-Maple Forests (G4?).

2. The Wadsworth Glenn contains the following communities: Hemlock-White Pine-Northern Hardwood Forest (G3/G4), oak-hickory forest, mixed floodplain forest, floating-leaved marsh, submergent marsh, emergent marsh, cat-tail marsh, and ponds. This area is approximately 90 acres.

3. The Group 3 woods is approximately 700 acres and contains mixed swamp forest, beech-sugar maple forest, oak-maple-tuliptree forest, red maple woods, successional woods, cat-tail marsh, and disturbed habitats.

4. The B&O Wye Road area contains Sphagnum thicket, oak-maple swamp forest, mixed swamp forest, dry fields, buttonbush swamp, wet meadows, cat-tail marsh, a pond, and seeps. This area consists of approximately 145 acres and is on the southeastern perimeter in Portage County on the Portage and Trumbull County line.

5. The South Patrol Road swamp forest is about 120 acres and contains mixed swamp forest, oak-maple swamp forest, beech-maple forest, buttonbush swamp, and open swamps.

G. Other Biological Items of Interest

1. Turkey Vulture Roosts – Turkey Vultures roost and breed throughout the RVAAP, primarily on and around earth-covered magazine headwalls and abandoned buildings.

2. Great Blue Heron – Up to three heron rookeries have been identified at the RVAAP in a given year. The rookeries are normally small and are abandoned for better areas from time to time.

NOTE: There are currently NO FEDERALLY listed species or critical habitat on the RTLS/RVAAP property.

2.7 PRELIMINARY CONCEPTUAL SITE MODEL

The facility-wide hydrogeologic CSM for RVAAP, presented in the Facility-wide SAP, is applicable to RQL for this Phase I RI, based on current knowledge. The CSM for RVAAP, operational information, and data collected during the Initial and Final Groundwater Investigations at RQL (USACE 1999; 2000) were used to develop the preliminary CSM, as outlined below. The preliminary CSM was used to develop sampling rationales and DQOs for the Phase I RI SAP Addendum No. 1. This preliminary CSM is refined to integrate the results of the evaluation of contaminant nature and extent, fate and transport modeling, and the HHRA and ERA and presents a summary of available knowledge for the AOC (Chapter 8.0).

Soil

Limited geologic and analytical data existed for soils at RQL prior to the Phase I RI; therefore, an accurate assessment has previously not been possible. Exposed bedrock or thin natural soil cover characterizes the ground surface. The landfill has a compacted-soil cover that is vegetated and appears to be intact. Sampling of soil within the AOC had not been conducted previous to the Phase I RI and was the target of biased and multi-increment sampling.

Sediment

Analysis of sediment samples collected during previous investigations detected multiple metals and cyanide. For trace metals, the maximum detected results, at a minimum, for every constituent exceeded the facility-wide background criteria. Trace metals were detected in all 12 samples collected, with the following exceptions: beryllium (9 detects), cadmium (4 detects), selenium (5 detects), and thallium (3 detects). Numerous SVOCs, primarily PAHs, were present in the sediment samples. Volatile constituents were sporadic, present at low concentrations, and limited to acetone, 2-butanone, and methylene chloride. Seven explosive compounds were detected at least once, the most persistent being 2,4,6-TNT (three detects) and HMX (eight detects). All values were estimated results less than reporting limits, with the exception of the maximum detected HMX values (0.14 mg/kg). Nitrocellulose was detected in three samples. Review of signature contaminants in the quarry pond sediments do not provide conclusive evidence that they act as a secondary source term. In wells immediately downgradient of the pond, explosives were detected on only one occasion, compared with several detections in upgradient wells. Additionally, PAHs were not detected in any of the site monitoring wells, and explosives, propellants, cyanide, and SVOCs were not detected in associated surface water samples, indicating that contaminant mass transfer from sediment to surface water with subsequent infiltration to groundwater is not a significant release mechanism. With the possible exception of metals, the pond does not appear to represent a significant source of contaminant flux to groundwater; thus, no further sediment sampling was planned during the Phase I RI.

Surface Water

Analytical data from RQL surface water sampling stations show that metals are the class of contaminants most frequently detected above background criteria. Sampling indicated that arsenic, chromium, copper, lead, manganese, mercury, and zinc concentrations exceeded facility-wide surface water background on at least two occasions. Iron and manganese exceeded their respective Ohio state-wide surface WQC; however, background values for these constituents also exceeded these criteria. Arsenic, iron, and manganese were the only constituents that regularly exceeded EPA Region 9 tap water PRGs. The majority of the metals detected above background occurred in the dry season September and October 1998 sampling events at RQLsw-015 when quarry pond water levels were extremely low, which likely produced evaporative concentration. Cyanide was detected only during the initial phase of work.

Explosives, propellants, VOCs, and SVOCs were largely absent in surface water collected both during the initial and follow-on phases of the Groundwater Investigation. Since 1998, the quarry pond has frequently been dry for extended periods. The surface water was believed to be adequately characterized; therefore, no additional sampling during the Phase I RI was planned.

Groundwater

Groundwater contains low, but consistently detectable, concentrations of explosive compounds and nitroglycerin. However, no explosives results exceeded EPA Region 9 tap water PRGs. Nitrobenzene; 2,4-dinitrotoluene (-DNT); and 1,3-dinitrobenzene (-DNB) were the most common detected explosives. Nitroglycerin was detected on three occasions in groundwater; no other propellants were detected. In addition to the major geochemical constituents (i.e., calcium, iron, magnesium, potassium, and sodium), multiple trace metals were present above facility-wide background criteria. Comparatively fewer results exceeded Ohio drinking water standards and EPA Region 9 tap water PRGs. The most prevalent trace metals were arsenic, cobalt, manganese, mercury, nickel, and zinc. Aluminum, beryllium, chromium, copper, lead, and selenium were sporadically detected above background criteria. Sporadic detections of bis(2-ethylhexyl)phthalate were noted. No VOC results exceeded Ohio primary MCLs and only one benzene result exceeded the EPA Region 9 tap water PRG. Toluene and methylene chloride were the most common detected VOCs.

Due to extremely dry conditions that persisted during the periods of previous investigations, water levels in the quarry pond were abnormally low. Therefore, the degree of recharge provided by the quarry pond has not been characterized under typical hydrologic conditions. During periods of normal precipitation, the pond would be expected to remain at full pool for longer periods of time. Accordingly, the duration and severity of observed groundwater flow reversals may differ substantially from those observed under the previous conditions. The additional Phase I RI wells for RQL were planned to better define flow gradients at the AOC.

Current Site Conditions

The nature and types of contaminants to be expected from RQL are largely unknown due to incomplete operational records and source term characterization. At the completion of the groundwater investigation, RQL was assumed, but not confirmed, as the primary source for groundwater contaminants, such as explosives, propellants, and VOCs. The current potential for human exposure to potential contaminants migrating from the site is mitigated by inactivity at the site, the absence of permanent residents, and the low population density on adjacent private properties.

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3.0 STUDY AREA INVESTIGATION

The Phase I RI field effort conducted in October 2003 through January 2004 at RQL included collection of surface soils using both discrete and multi-increment techniques, as well as the installation, sampling, and slug testing of six new monitoring wells. Subsurface soil, sediment, and surface water sampling were not included in the scope of field activities. The scheduled plugging and abandonment of five existing wells comprising the original RQL monitoring well network was also scheduled to be completed as part of the Phase I RI field activities. However, upon attempting to plug and abandon the wells, it was discovered that the borehole and well casing diameters were much larger than estimated from best available records. Additionally, the borehole depths were discovered to be much deeper than originally believed and the lower portions of the borings had been backfilled prior to setting screens. Thus, larger drilling equipment was determined to be needed and the abandonment was re-scheduled for completion at a later time.

This chapter presents information on the locations of, and the rationale for, samples collected during this field effort, and provides a description of the sampling methods employed during the investigation. Specific notation is made where site conditions required a departure from planned activities detailed in the SAP Addendum No. 1 for the RQL Phase I RI (USACE 2003b). Information regarding standard field decontamination procedures, sample container types, preservation techniques, sample labeling, chain-of-custody, and packaging and shipping requirements implemented during the field investigation can be found in the Facility-wide SAP (USACE 2001) and SAP Addendum No. 1 (USACE 2003b).

Proposed Phase I RI sample locations were reviewed by representatives of RVAAP, Ohio EPA, and USACE as part of the concurrence process for the SAP Addendum No. 1. The rationale for each component of the field investigation is described in the following sections.

3.1 SOIL AND VADOSE ZONE CHARACTERIZATION

The collection of surface soil samples at RQL was intended to assess contaminant occurrence and distribution, if any, in surface soil within the bottom of the quarry. Phase I RI surface soil samples were collected from 0 to 1 ft at a total of 15 sampling stations located in the bottom of Ramsdell Quarry, exclusive of the pond and landfill toe slope. Both discrete (ten sample stations) and multi-increment (five sampling areas) sampling methods were employed. Figure 3-1 illustrates locations of the discrete soil sampling locations for the Phase I RI and shows the boundaries of each multi-increment sampling zone. Table 3-1 provides details on locations, rationales, sample depths, and other field information for all soil sample collection activities during the Phase I RI.

3.1.1 Rationale

Surface soil sampling involved the combination of both discrete and multi-increment sampling to provide a general characterization of the quarry bottom, as well as suspected contaminant accumulation points. Discrete surface soil samples were collected from the 0 to 1-ft interval at ten stations during the RI. Discrete surface soil samples were collected to obtain requisite data for the purposes of risk evaluations. Discrete sample locations were pre-located by the sampling crew with the support of MEC technicians. Final sample locations, relative to the proposed locations in the Phase I RI SAP Addendum No. 1, were moved minimally only if standing water was found to be present at the proposed location or magnetometer surveys indicated the presence of metallic debris.

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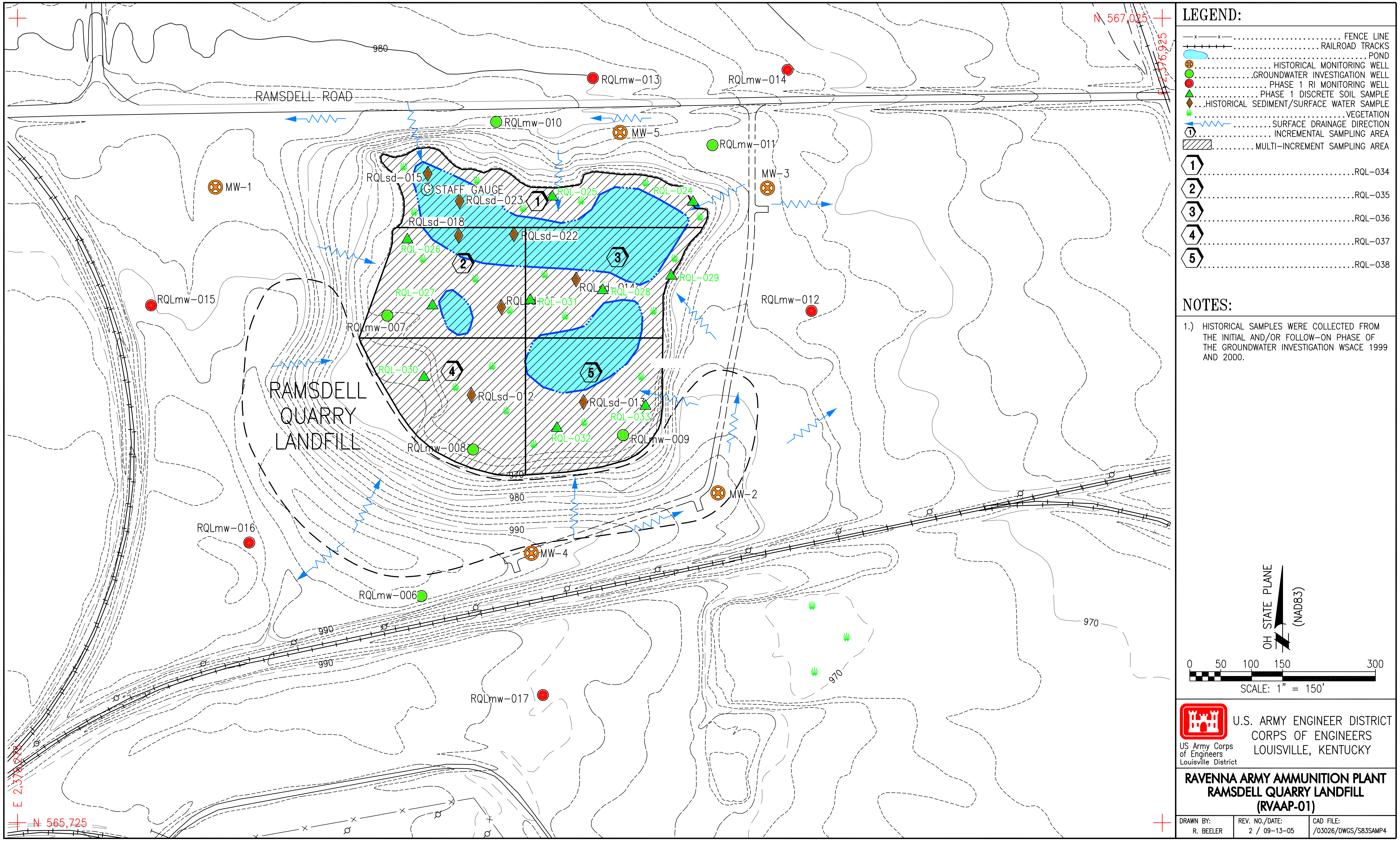

Figure 3-1. Ramsdell Quarry Site Map and Groundwater Sampling Locations

Table 3-1. Soil Sample List and Rationales, Ramsdell Quarry Landfill Phase I Remedial Investigation

Facility/Area	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments/Rationales
Discrete Surface Soil Locations (ten)	0 to 1	RQL-024	RQLss-024-0124-SO	Y	11/03/2003	Duplicate (RQLss-0157) and Split (RQLss-0158) also collected
	0 to 1	RQL-025	RQLss-025-0125-SO	Y	11/03/2003	
	0 to 1	RQL-026	RQLss-026-0126-SO	Y	11/04/2003	Refusal at 0.8 ft
	0 to 1	RQL-027	RQLss-027-0127-SO	Y	11/04/2003	Refusal at 0.8 ft
	0 to 1	RQL-028	RQLss-028-0128-SO	Y	11/04/2003	Refusal at 0.5 ft
	0 to 1	RQL-029	RQLss-029-0129-SO	Y	11/04/2003	Refusal at 0.5 ft
	0 to 1	RQL-030	RQLss-030-0130-SO	Y	11/04/2003	
	0 to 1	RQL-031	RQLss-031-0131-SO	Y	11/04/2003	Refusal at 0.7 ft
	0 to 1	RQL-032	RQLss-032-0132-SO	Y	11/04/2003	
	0 to 1	RQL-033	RQLss-033-0133-SO	Y	11/04/2003	
Multi-Increment Surface Soil Locations (five)	0 to 1	RQL-034	RQLss-034-0134-SO	Y	11/05/2003	
	0 to 1	RQL-035	RQLss-035-0135-SO	Y	11/05/2003	
	0 to 1	RQL-036	RQLss-036-0136-SO	Y	11/05/2003	
	0 to 1	RQL-037	RQLss-037-0137-SO	Y	11/04/2003	
	0 to 1	RQL-038	RQLss-038-0138-SO	Y	11/04/2003	

ID = Identifier.

The Phase I RI for Ramsdell Quarry represented one of the first applications of multi-increment sampling techniques. These samples were collected for the purposes of evaluating field implementation of the method and whether it could potentially be applied for characterization of other AOCs at RVAAP. A qualitative assessment of these data is presented in Chapter 4.0 of this Phase I RI report.

3.1.2 Surface Soil Field Sampling Methods

Methods used for the collection of surface soil samples during the Phase I RI are summarized in the following sections. Detailed presentation of the procedures used to collect discrete soil samples are presented in the Phase I RI SAP Addendum No. 1 and Facility-wide SAP. A detailed procedure for collection of multi-increment samples is not included in the Facility-wide SAP; therefore, a procedure was developed by USACE and included in the Phase I RI SAP Addendum No 1. Subsurface soils were not collected during the RQL Phase I RI.

3.1.2.1 Discrete soil sampling

Discrete surface soil samples were collected using a stainless steel hand auger in accordance with Section 4.5.2.1.1 of the Facility-wide SAP.

For explosives and propellants analyses, surface soils were collected from three subsamples located approximately 3 ft from one another in a roughly equilateral triangle pattern and homogenized to obtain a representative sample. Equal portions of soil from the three soil subsamples were placed into a decontaminated, stainless steel bowl and mixed thoroughly with a decontaminated, stainless steel spoon before placement into appropriate sample containers.

Surface soil samples for all analyses other than explosives or propellants (i.e., inorganics, SVOCs, VOCs, etc.) were collected from a point in the approximate center of the triangle from which the explosives and propellant samples noted above were collected. Samples for VOCs were collected from the center of the triangle and placed directly into sample containers without mixing the soil. The remaining soil collected from the center of the triangle was placed into a decontaminated, stainless steel bowl, mixed thoroughly with a decontaminated stainless steel spoon, and placed into appropriate sample containers.

Field screening of discrete soil samples for organic vapors was performed using a photoionization detector (PID). No elevated PID readings were noted during the Phase I RI. Samples for headspace analysis were not collected

3.1.2.2 Multi-increment samples

The bottom of Ramsdell Quarry, exclusive of the pond and landfill toe slope, was divided into five separate areas, each approximately equal in terms of acreage (Figure 3-1). The boundaries of each area were roughly marked in the field with wooden stakes and flagging tape. One multi-increment composite sample was collected from each of the five areas. Each multi-increment sample was comprised of a minimum of 30 sample aliquots collected over the entire area of each zone, with the exception of those areas covered by standing water. A minimum of 30 aliquots was collected from each sample area to provide statistical confidence that the average concentration of a particular constituent within a designated area was represented by the sample. The individual sample points, from which aliquots were collected, were located using a "random walk" technique employed in the field; sample points were not pre-located. Each sample aliquot was collected from the 0 to 1 ft depth interval using a 21-in. long, 0.875-in. outside diameter, 0.68-in. inside diameter, stainless steel soil probe. The soil probe collected a 10-in. soil core and was either hand-pushed or driven with a hammer into the ground.

Sample aliquots were composited in stainless steel bowls. The entire composited contents of each sample were mixed thoroughly and air-dried. After drying, each sampled was sieved using Nos. 4 and 10 brass sieves. Sieved samples were then spread onto aluminum trays for further drying. Once fully dry, a minimum of 30 random aliquots were collected and placed into the appropriate sample containers until the requisite volume was attained for analysis by the contract laboratory. Upon receipt of samples, the contract laboratory ground each sample for 20 to 30 seconds and further mixed the sample to achieve a high degree of homogeneity. Where QA splits were specified, the primary laboratory provided a split of the ground, fully processed sample to the QA laboratory.

Field screening or headspace analysis for organic vapors was not conducted on multi-increment samples. Multi-increment samples were analyzed for TAL metals, explosives, cyanide, and SVOCs. One sample also was analyzed for propellants and pesticides/PCBs. Analysis for VOCs was also not performed on multi-increment samples.

3.2 GROUNDWATER CHARACTERIZATION

Previous groundwater characterization at Ramsdell Quarry indicated the presence of explosives contaminants, generally at low levels. Explosives were detected in some downgradient wells and in well RQLmw-006, which is predominantly upgradient of the quarry except during periods of high precipitation. Accordingly, six new groundwater monitoring wells were installed and sampled as part of the RQL Phase I RI to further assess groundwater contamination and potential migration pathways.

3.2.1 Rationale

Table 3-2 presents the specific rationale for the placement of each new Phase I RI monitoring well. In general, the Phase I RI wells were located based on the results of a Groundwater Study at Ramsdell Quarry conducted in 1998 and 1999 (USACE 1999; 2000). Monitoring wells were located to either fill gaps in the monitoring network coverage or to define the maximum extent of explosives detected during previous studies.

Table 3-2. Rationale for Placement of Monitoring Wells at Ramsdell Quarry

Well ID	Location	Rationale
RQLmw-013	Along north side of Ramsdell Road	Provide data on general hydrogeologic characteristics and groundwater flow patterns. Define the extent of explosives contaminants in the downgradient direction
RQLmw-014	Along north side of Ramsdell Road	Provide data on general hydrogeologic characteristics and groundwater flow patterns. Define the extent of explosives contaminants in the downgradient direction
RQLmw-012	East of RQL	Provide data on general hydrogeologic characteristics and groundwater flow patterns. Provide closure for the monitoring network in the side-gradient direction
RQLmw-015	West of RQL	Fill data gap in this portion of the AOC
RQLmw-016	Southwest of RQL	Fill data gap in this portion of AOC and to monitor for potential northward contaminant transport from Load Line 1
RQLmw-017	South of AOC, between RQL and Load Line 1	Determine whether contaminants observed in the upgradient well at Ramsdell Quarry (RQLmw-006) are sourced from Load Line 1

AOC = Area of concern.
ID = Identifier.
RQL = Ramsdell Quarry Landfill.

3.2.2 Monitoring Well Installation Methods

Monitoring well installation was conducted in accordance with Sections 4.1.1 and 4.1.2 of the RQL Phase I RI SAP Addendum No. 1 and Section 4.3.2.1.2 of the Facility-wide SAP. Monitoring wells were installed using hollow-stem auger and air rotary drilling methods, as required, under the direct supervision of a qualified geologist. Continuous soil sampling was conducted within the unconsolidated zone using a 4.25-in. hollow-stem auger and 2-ft split-spoon sampler. Soil descriptions, Unified Soil Classification System classification, and color determination using standard Munsell® soil color charts were performed. Refusal on bedrock occurred at all wells at shallow depths. Bedrock intervals were cored and the cores logged to describe bedrock stratigraphy and to determine the degree and nature of weathering and fracturing in the bedrock. All rock cores were stored in specification wooden core boxes in a manner that preserved their relative depths. A borehole log, including all lithologic information, was entered in the project logbooks for each monitoring well boring. Monitoring well boring logs are provided in Appendix B. Following the drilling of coreholes to the target depth, the coreholes were reamed to the requisite diameter using a 6.25-in. tri-cone bit for subsequent well installation.

Organic vapors were screened using a hand held PID from well cuttings and along the surface of cores obtained during well installation. The breathing zone was continuously monitored for evidence of organic chemicals. Headspace readings were not conducted per the Phase I RI SAP Addendum No. No elevated PID readings were noted during drilling operations. All readings were recorded in the project logbooks.

Following drilling of monitoring well boreholes to appropriate specifications, monitoring wells were constructed using pre-cleaned, 2.0-in. inside diameter, schedule 40 polyvinyl chloride (PVC) riser casing. All wells were constructed using 10-ft screens. Well screens were commercially fabricated with slot widths of 0.010-in. The well casing and screen were assembled and lowered into the open borehole. Following placement of well screen and riser casing, a filter pack consisting of #7 silica sand was tremied in to approximately 3 to 4 ft above the top of the well screen. A 3- to 5-ft thick annular seal consisting of 3/8-in. bentonite chips was then poured into the borehole on top of the filter pack.

For monitoring well completion, a grout mixture consisting of Type I Portland cement and 2% Bentonite was then tremied in from the top of the annular seal to the ground surface. All wells had above-grade completions in accordance with Section 4.3.2.3.9 of the Facility-wide SAP (USACE 2001), including a protective steel surface casing, mortar collar, and protective pad. Each pad was set with a small brass plate and the well identifier (ID) stamped into the plate. Four steel traffic posts were installed around each well approximately 4 ft apart and painted high-visibility yellow. Well construction diagrams, provided in Appendix B, summarize the construction details for the monitoring wells installed during the Phase I RI at RQL, including depths, screened intervals, and groundwater elevations. This information is summarized in Table 3-3.

Table 3-3. Summary of Ramsdell Quarry Monitoring Well Construction Data

Well ID	Total Depth (ft)	Elevation (GL)	Elevation (TOC)	Screened Interval (ft below GL)	Lithology in Screened Interval
RQLmw-012	30.5	975.12	977.65	19.8 to 29.8	Sandstone
RQLmw-013	34.4	978.04	980.71	23.7 to 33.7	Sandstone
RQLmw-014	29.4	970.83	973.49	18.57 to 28.57	Sandstone
RQLmw-015	40.1	989.19	991.26	29.17 to 39.17	Sandstone
RQLmw-016	39.5	994.02	996.60	28.5 to 38.5	Sandstone
RQLmw-017	30.5	988.69	991.23	19.78 to 29.78	Sandstone

GL = Ground level.
ID = Identifier.
TOC = Top of casing

3.2.3 Well Development Methods

Each new monitoring well was developed so that representative groundwater samples could be collected. Well development was accomplished with a pump or bailer, as per section 4.3.2.3.11 of the Facility-wide SAP. Due to comparatively slow recharge rates, three of the wells were developed using disposable bailers (RQLmw-015, -016, and -017). Development was continued until the following criteria were met:

- Turbidity readings of 5 nephelometric turbidity units or less were attained, or until water was clear to the unaided eye, or until the maximum 48-hr development time had elapsed.
- The sediment thickness remaining in the well was less than 1% of the screen length.
- A minimum of 5 times the standing water volume in the well was purged.
- Indicator parameters (pH, temperature, and specific conductance) had stabilized to ±10% over three successive well volumes.

The wells were developed and purged prior to sampling in accordance with work plan specifications to obtain the lowest possible turbidity readings. Micropurge sampling methods were employed for wells where possible (recharge rates were too slow at RQLmw-015, -016, and -017). Despite these measures, turbidity levels remained above 5 nephelometric turbidity units in most wells. All other parameters (temperature, specific conductivity, and pH) had stabilized to meet the criteria specified in the work plan. Accordingly, only filtered metals samples were obtained.

Monitoring well development records were recorded on appropriate forms in field logbooks and are provided in Appendix B.

3.2.4 Groundwater Field Sampling Methods

Groundwater samples were collected from each of the six new monitoring wells following development and AOC-wide water level measurements. The procedure for sampling is detailed in Section 4.3.4.2 of the Facility-wide SAP. Before sampling, each monitoring well was purged using a portable bladder pump where conditions permitted, following low-flow sampling methods, until readings of pH, specific conductance, and water temperature reached equilibrium. Recharge rates in wells RQLmw-015 and -016 were insufficient to allow the use of low-flow sampling methods. Both wells were pumped dry, sufficient time was allowed for groundwater recharge, then sampling was performed using disposable bailers. Well RQLmw-017 also had slow recharge; therefore, the well was bailed dry using disposable bailers, then allowed to recharge before final sampling was conducted with the same bailer. Where low-flow sampling methods were employed, general groundwater quality parameters were monitored continuously using a flow cell device. An Horiba water quality instrument was employed to monitor general water quality parameters for those wells sampled by bailer.

All groundwater samples from RQL were analyzed for TAL metals (filtered only), explosives, propellants, cyanide, VOCs, SVOCs, and pesticides/PCBs. Groundwater samples analyzed for TAL metals were filtered during sample collection using an in-line, disposable barrel filter with 0.45-um pores. For those wells with slow recharge rates where micro-purge techniques were not applicable, samples for TAL metals were filtered using a negative pressure, hand-operated vacuum pump and collection flask with a 0.45-um pore size filter. Groundwater sampling logs are presented in Appendix H; sampling results are discussed in detail in Section 4.6. Table 3-4 provides a summary of groundwater sample information for the Phase I RI.

Table 3-4. Groundwater Sample List, Ramsdell Quarry Landfill Phase I Remedial Investigation

Well ID	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments
RQLmw-012	RQLmw-012-0139-GW	Y	12/02/2003	
	RQLmw-012-0160-GW	Y	12/02/2003	Duplicate
	RQLmw-012-0163-GW	Y	12/02/2003	Split
RQLmw-013	RQLmw-013-0140-GW	Y	12/02/2003	
RQLmw-014	RQLmw-014-0141-GW	Y	12/02/2003	MS/MSD
RQLmw-015	RQLmw-015-0142-GW	Y	12/03/2003	
RQLmw-016	RQLmw-016-0143-GW	Y	12/04/2003	
RQLmw-017	RQLmw-017-0144-GW	Y	12/02/2003	

ID = Identifier.
MS/MSD = Matrix spike/matrix spike duplicate.

3.2.5 In Situ Permeability Testing

Slug tests were performed at newly installed monitoring wells to determine the hydraulic conductivity of the geologic materials surrounding each well screen. Slug tests followed the provisions of the SAP Addendum No. 1 for the RQL RI. These analyses calculate horizontal hydraulic conductivities in the screened interval of each well. Both falling head and rising head slug tests were performed on all wells, except RQLmw-016 and -017, to provide confirmatory data. Due to slow recharge in RQLmw-016 and -017, falling heads were not performed, rather a rising head test was repeated. The falling head test was performed by rapidly inserting a PVC cylinder into the well and monitoring the return of the water level to static conditions. The rising head test was performed immediately following the conclusion of the falling head test, and was accomplished by removing the slug and monitoring the rise in water levels. The tests were performed after each well had fully recovered from groundwater sampling. The PVC cylinder (slug) employed for all tests was designed to displace 1 ft of water.

Pressure transducers and data loggers were used for automated data collection during slug tests. Water level measurements were recorded using a pre-programmed logarithmic time interval. Water levels were monitored until the well re-equilibrated to 90% of the pre-test water level or a maximum of 6 hrs had elapsed. The data were evaluated using AqteSolve^{TM}; hydraulic conductivity values were derived using the Bouwer and Rice method. The results of slug tests are presented in Appendix D and are discussed in Chapter 2.0.

3.3 ANALYTICAL PROGRAM OVERVIEW

All analytical procedures and data verification/evaluation processes were completed in accordance with applicable professional standards, EPA requirements, government regulations and guidelines, Louisville District analytical QA guidelines, and specific project goals and requirements, as defined in the Phase I RI SAP Addendum No. 1 for the RQL.

3.3.1 Field Analyses for Explosives

No field analyses for explosives were conducted for the RQL Phase I RI.

3.3.2 Geotechnical Analyses

The geotechnical sampling and analysis program conducted during the Phase I RI for RQL involved the collection of surface soils only. No geotechnical samples were collected; however, chemical analysis of discrete surface soil samples included total organic carbon (TOC). The results of TOC analyses can be found in Appendix H.

3.3.3 Laboratory Analyses

All analytical procedures were completed in accordance with applicable professional standards, EPA requirements, government regulations and guidelines, USACE, Louisville District analytical QA guidelines, and specific project goals and requirements. The sampling and analysis program conducted during the Phase I RI for RQL involved the collection and analysis of surface soil and groundwater. Field screening for organic vapors was conducted at each sampling location using a PID; however, headspace readings were not performed.

Samples collected during the investigation were analyzed by GPL Environmental (GPL) of Gaithersburg, Maryland, a USACE Center of Excellence-certified laboratory. QA split samples collected for surface soil and groundwater were analyzed by USACE's contracted QA laboratory, Severn Trent Laboratories of North Canton, Ohio. Laboratories involved in this work have statements of qualifications including organizational structures, QA manuals, and standard operating procedures (SOPs), which are available upon request.

Samples were collected and analyzed according to the Facility-wide SAP and the SAP Addendum No. 1 for the RQL Phase I RI. Prepared in accordance with USACE and EPA guidance, the Facility-wide SAP and associated addenda outline the organization, objectives, intended data uses, and QA/quality control (QC) activities to achieve the desired DQOs and to maintain the defensibility of the data. Project DQOs were established in accordance with EPA Region 5 guidance. Requirements for sample collection, handling, analysis criteria, target analytes, laboratory criteria, and data validation criteria for the Phase I RI are consistent with EPA requirements for National Priorities List sites. DQOs for this project included analytical precision, accuracy, representativeness, completeness, comparability, and sensitivity for the measurement data. Appendix G presents an assessment of those objectives as they apply to the analytical program.

Strict adherence to the requirements set forth in the Facility-wide SAP and project addenda was required of the analytical laboratory so that conditions adverse to quality would not arise. The laboratory was required to perform all analyses in compliance with EPA SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Analytical Protocols* (EPA 1990b). SW-846 chemical analytical procedures were followed for the analyses of metals, VOCs, SVOCs, pesticides, PCBs, explosives, propellants (except nitrocellulose and nitroguanidine), and cyanide. Laboratories were required to comply with all methods as written; recommendations were considered requirements. Analytical procedures for nitrocellulose and nitroguanidine are proprietary laboratory methods.

QA/QC samples for this project included field blanks, trip blanks, QA field duplicates, QC split samples, laboratory method blanks, laboratory control samples (LCSs), laboratory duplicates, and matrix spike/matrix spike duplicate samples. Field blanks, consisting of potable water used in the decontamination process, equipment rinsate blanks, and trip blanks were submitted for analysis, along with field duplicate samples, to provide a means to assess the quality of the data resulting from the field sampling program. Table 3-5 presents a summary of QA/QC samples utilized during the Phase I RI. Evaluation of these QA/QC samples and their contribution to documenting the project data quality is provided in Appendix G.

Table 3-5. Summary of QA/QC Samples, Ramsdell Quarry Landfill Phase I Remedial Investigation

Sample Type	Rationale
Field Blank	Analyzed to determine procedural contamination at the site that may contribute to sample contamination
Trip Blank	Analyzed to assess the potential for contamination of samples due to contaminant interference during sample shipment and storage
Field Duplicate	Analyzed to determine sample heterogeneity and sampling methodology reproducibility
Equipment Rinsate	Analyzed to assess the adequacy of the equipment decontamination processes for soil and groundwater
Laboratory Method Blanks	Analyzed to determine the accuracy and precision of the analytical method as implemented by the laboratory
Laboratory Duplicate Samples	Analyzed to assist in determining the analytical reproducibility and precision of the analysis for the samples of interest and provide information about the effect of the sample matrix on the measurement methodology
Matrix Spike/Matrix Spike Duplicate	
QC Split	Analyzed to provide independent verification of the accuracy and precision of the principal analytical laboratory

QA = Quality assurance.
QC = Quality control.

SAIC is the custodian of the project file and will maintain the contents of the files for this investigation, including all relevant records, reports, logs, field notebooks, pictures, subcontractor reports, correspondence, and chain-of-custody forms. These files will remain in a secure area under the custody of the SAIC project manager, until they are transferred to USACE, Louisville District and RVAAP. Analytical data reports from the project laboratory have been forwarded to the USACE, Louisville District laboratory data validation contractor (Laboratory Data Consultants, Inc.) for validation review and QA comparison. GPL will retain all original raw data (both hardcopy and electronic) in a secure area under the custody of the laboratory project manager.

3.3.4 Data Review, Validation, and Quality Assessment

Samples were properly packaged for shipment and dispatched to GPL for analysis. A separate signed custody record with sample numbers and locations listed was enclosed with each shipment. When transferring the possession of samples, the individuals relinquishing and receiving signed, dated, and noted the time on the record. All shipments were in compliance with applicable U. S. Department of Transportation regulations for environmental samples.

Data were produced, reviewed, and reported by the laboratory in accordance with specifications outlined in the Facility-wide SAP, the SAP Addendum No for the RQL RI, the Louisville District analytical QA guidelines, and the laboratory's QA manual. Laboratory reports included documentation verifying analytical holding time compliance.

GPL performed in-house analytical data reduction under the direction of the laboratory project manager and QA officer. These individuals were responsible for assessing data quality and informing SAIC and USACE of any data that are considered "unacceptable" or required caution on the part of the data user in terms of its reliability. Data were reduced, reviewed, and reported as described in the laboratory QA manual and SOPs. Data reduction, review, and reporting by the laboratory were conducted as follows:

- Raw data produced by the analyst were turned over to the respective area supervisor.

- The area supervisor reviewed the data for attainment of QC criteria, as outlined in the established methods and for overall reasonableness.

- Upon acceptance of the raw data by the area supervisor, a report was generated and sent to the laboratory project manager.

- The laboratory project manager completed a thorough review of all reports.

- Final reports were generated by the laboratory project manager.

Data were then delivered to SAIC for data verification. GPL prepared and retained full analytical and QC documentation for the project in both paper copy and electronic storage media (e.g., compact disk), as directed by the analytical methodologies employed. GPL provided the following information to SAIC in each analytical data package submitted:

- cover sheets listing the samples included in the report and narrative comments describing problems encountered in analysis;

- tabulated results of inorganic and organic compounds identified and quantified; and

- analytical results for QC sample spikes, sample duplicates, initial and continuing calibration verifications of standards and blanks, method blanks, and LCS information.

A systematic process for data verification was performed by SAIC to ensure that the precision and accuracy of the analytical data were adequate for their intended use. This verification also attempted to minimize the potential of using false-positive or false-negative results in the decision-making process (i.e., to ensure accurate identification of detected versus non-detected compounds). This approach was consistent with the DQOs for the project and with the analytical methods, and was appropriate for determining contaminants of concern and calculating risk. Samples were identified through implementation of "definitive" analytical methods. "Definitive Data" were reported consistent with the deliverables identified in the project SAP. These definitive data were then verified through the review process outlined in the project SAP. Following data verification, all data packages were forwarded to the USACE independent data validation contractor.

Independent data validation was performed by Laboratory Data Consultants, Inc., under a separate task with USACE, Louisville District. This review constituted comprehensive validation of 10% of the primary dataset; comprehensive validation of the QA split sample dataset; and a comparison of primary sample, field duplicate sample, and field QA split sample information.

3.4 MUNITIONS AND EXPLOSIVES OF CONCERN AVOIDANCE AND FIELD RECONNAISSANCE

A qualified MEC subcontractor, approved by the USACE Huntsville MEC Mandatory Center of Excellence, provided MEC avoidance support during all field activities, except groundwater sampling and in situ hydraulic conductivity testing (slug testing). The MEC team leader led an initial safety briefing on MEC avoidance to train all field personnel to recognize and stay away from propellants and MEC. Daily tailgate safety briefings included reminders regarding MEC avoidance. Site visitors were briefed on MEC avoidance prior to allowing them access into the AOC.

The MEC avoidance technicians used Schonstedt Models GA-52 and GA-72 (or equivalent) magnetic locators for surface anomaly surveys, and a Schonstedt Model MG-220 magnetic gradiometer (or equivalent) for all downhole surveys. Prior to beginning sampling activities, access routes into areas from which samples were to be collected were assessed for potential MEC using visual surveys and hand-held magnetometers. The MEC team leader, USACE technical representative, and SAIC technical manager located each proposed soil, sediment, and groundwater monitoring well location within the AOC using a steel pin flag with the sample station ID number. The pin flag was placed at a point approved by the MEC technician. A MEC technician remained with the sampling crews as work progressed.

For monitoring well borings, MEC technicians screened the locations by hand augering to a minimum depth of at least 2 ft below original undisturbed soil or until bedrock was encountered, whichever was more, and performed downhole magnetometer readings at 2-ft intervals. The MEC technician remained on-site as drilling was performed to visually examine drill cuttings for any unusual materials indicative of potential MEC. The MEC reconnaissance results at RQL are summarized in Chapter 4.0 and presented in Appendix J in their entirety.

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4.0 NATURE AND EXTENT OF CONTAMINATION

This chapter presents results of the Phase I RI data screening process to identify site-related contaminants (SRCs) indicative of impacts from AOC operations, and to evaluate occurrence and distribution of SRCs in environmental media at Ramsdell Quarry. The data incorporated in the evaluation include those only from the Phase I RI investigation, which were collected in December 2003. A discussion of data collected during previous investigations at Ramsdell Quarry is presented in Section 1.3.2.

Section 4.1 of this chapter presents the statistical methods and facility-wide background screening criteria used to distinguish constituents present at ambient concentrations from those present at concentrations that indicate potential impacts related to historical operations within the AOC. Sections 4.2, 4.3, and 4.4 present the nature and extent of identified SRCs within each environmental media and spatial data aggregates [surface soil (discrete and multi-increment samples) and groundwater] established for this Phase I RI Report. A summary of the results of the MEC avoidance survey is presented in Section 4.4. Summary analytical results are presented in graphical or tabular formats in the sections addressing each data aggregate. Complete analytical results are in Appendix G.

4.1 DATA EVALUATION METHODS

The data evaluation methods for the RQL Phase I RI are consistent with those established under multiple previous Phases I and II investigations at RVAAP. These methods were specified in the RQL Phase I RI SAP Addendum No. 1 (USACE 2003b). The processes used to evaluate RQL Phase I RI analytical data involved four general steps: (1) defining background concentrations, (2) defining data aggregates, (3) reducing and screening data, and (4) presenting data.

4.1.1 Site Chemical Background

Chemicals occur naturally in soils, sediments, surface water, and groundwater. Some constituents are introduced to the environment through anthropogenic means other than RVAAP-related operations (pre-RVAAP farming and homestead sites, burning of fossil fuels, etc.). The ambient levels of chemicals—called background levels—must be known to determine whether the concentrations measured at RQL are higher than would be expected if AOC operations had not occurred. Analytical results were screened against the final facility-wide background values for RVAAP as presented in the Phase II RI for WBG (USACE 2001c). These facility-wide background criteria (including soil, sediment, surface water, and groundwater media) and the processes used to generate them have been reviewed; accepted by RVAAP, USACE, and Ohio EPA; and employed in multiple subsequent RIs.

Although some organic compounds may occur under ambient conditions (i.e., some PAHs), the organic compounds of primary concern at RVAAP (e.g., explosives and PCBs) are man-made and; therefore, any detected concentration of organic compounds is considered as being above background.

For inorganic constituents in each environmental medium of interest, a RVAAP facility-wide background level was calculated for constituents detected in the background sample population. The background level for a specific constituent is the lower of the maximum detected value in the background data set (for non-normally distributed data) or the 95% upper tolerance limit of the 95th percentile of the distribution of background concentrations (for normally distributed or log-normally distributed data). For all inorganics detected in the RVAAP background data set, the background value selected was the maximum detected value. If a measured concentration of an inorganic constituent at an AOC is above the background criteria, it is likely that the concentration is elevated due to processes or operations that took place within that AOC.

If an inorganic constituent was not detected in the population of background samples, then its background criterion was set to zero. For those inorganics that were not detected in the background samples, any detected result from Ramsdell Quarry would be considered above background. RVAAP facility-wide background criteria for each medium are listed in Table 4-1.

4.1.2 Definition of Aggregates

Data collected from RQL were aggregated by environmental medium (surface soil and groundwater) to produce statistical summaries, conduct the nature and extent assessment, and perform the risk screening. These data aggregates were selected to be consistent with the facility-wide background criteria and risk screening approach.

As discussed in detail in Chapter 3.0, surface soil samples included collection of both discrete and multi-increment composite samples. Discrete soil sample data only were aggregated by depth interval (0 to 1 ft) below ground surface. Data within the environmental media aggregates were evaluated to determine if further subdivisions (spatial aggregates) may be made on the basis of site operational history and hydrogeologic characteristics, and potential future land use (i.e., former waste disposal areas versus non-disposal areas). For RQL, it was determined that a single spatial aggregate encompassing the bottom of the quarry was sufficient for data evaluation and risk screening purposes. Likewise, for groundwater, one aggregate encompassing all of the newly installed Phase I RI monitoring wells was determined to be sufficient for data evaluation and risk screening purposes.

Summary statistics [i.e., minimum concentration, maximum concentration, frequency of detection, mean concentration, and 95% upper confidence limit (UCL_{95})] were developed for each aggregate on an AOC-wide basis. Source areas ("hot spots") were identified spatially from the data. Focused discussion of any prevalent SRC that occurs consistently across the AOC and any hot spots is presented in the contaminant occurrence and distribution evaluation. Evaluation of the spatial distribution of contaminants included factors such as proximity to sources and surface and groundwater flow patterns in the vicinity of the AOC.

The population of multi-increment composite samples collected at RQL was not aggregated for evaluation purposes nor were summary statistics generated because each sample represents the average concentration within the designated sampling area selected for characterization.

4.1.3 Data Reduction and Screening

4.1.3.1 Data verification and reduction

Thirty-three environmental surface soil, groundwater, and field QC samples were collected with approximately 3,600 discrete analyses (i.e., analytes) being obtained, reviewed, and integrated into this Phase I RI. These totals do not include field measurements and field descriptions. Analytical results were reported by the laboratory in electronic format and loaded into a database. As discussed in Section 3.6, verification of data was performed to ensure all requested data were received and complete. Data use qualifiers were assigned to each result based on the laboratory QA review and verification criteria. Results were qualified as follows:

- "U" not detected;
- "UJ" not detected, reporting limit estimated;

Table 4-1. RVAPP Facility-wide Background Criteria

Media Units Analyte	Surface Soil (mg/kg)	Subsurface Soil (mg/kg)	Sediment (mg/kg)	Surface Water (µg/L)	Groundwater Bedrock Zone Filtered (µg/L)	Groundwater Bedrock Zone Unfiltered (µg/L)	Groundwater Unconsolidated Zone Filtered (µg/L)	Groundwater Unconsolidated Zone Unfiltered (µg/L)
Cyanide	0	0	0	0	0	0	0	0
Aluminum	17,700	19,500	13,900	3,370	0	9,410	0	48,000
Antimony	0.96	0.96	0	0	0	0	0	4.3
Arsenic	15.4	19.8	19.5	3.2	0	19.1	11.7	215
Barium	88.4	124	123	47.5	256	241	82.1	327
Beryllium	0.88	0.88	0.38	0	0	0	0	0
Cadmium	0	0	0	0	0	0	0	0
Calcium	15,800	35,500	5,510	41,400	53,100	48,200	115,000	194,000
Chromium	17.4	27.2	18.1	0	0	19.5	7.3	85.2
Cobalt	10.4	23.2	9.1	0	0	0	0	46.3
Copper	17.7	32.3	27.6	7.9	0	17	0	289
Iron	23,100	35,200	28,200	2,560	1,430	21,500	279	195,000
Lead	26.1	19.1	27.4	0	0	23	0	183
Magnesium	3,030	8,790	2,760	10,800	15,000	13,700	43,300	58,400
Manganese	1,450	3,030	1,950	391	1,340	1,260	1,020	2,860
Mercury	0.036	0.044	0.059	0	0	0	0	0.25
Nickel	21.1	60.7	17.7	0	83.4	85.3	0	117
Potassium	927	3,350	1,950	3,170	5,770	6,060	2,890	7,480
Selenium	1.4	1.5	1.7	0	0	0	0	5.7
Silver	0	0	0	0	0	0	0	0
Sodium	123	145	112	21,300	51,400	49,700	45,700	44,700
Thallium	0	0.91	0.89	0	0	0	0	2.4
Vanadium	31.1	37.6	26.1	0	0	15.5	0	98.1
Zinc	61.8	93.3	532	42	52.3	193	60.9	888

RVAAP = Ravenna Army Ammunition Plant.

- “J” analyte present but at an estimated concentration less than the reporting limit;
- “R” result not usable; and
- “=” analyte present and concentration accurate.

In addition to assigning qualifiers, the verification process also selected the appropriate result to use when re-analyses or dilutions were performed. Where laboratory surrogate recovery data or laboratory QC samples were outside of analytical method specifications, a determination was made whether laboratory re-analysis should be used in place of an original reported result. If results were reported for both diluted and undiluted samples, results from the diluted sample were used only for those analytes that exceeded the calibration range of the undiluted sample. A complete discussion of the results of the verification process is contained in the data quality summary report (Appendix G). Independent validation of 10% of the Phase I RI data and 100% of the USACE QA laboratory data is performed by a third-party subcontractor to the USACE, Louisville District. Additional qualification of the Phase I RI data may be required based on the results of the validation process.

The data reduction process employed to identify SRCs involved first calculating data summary statistics. Site data were extracted from the database such that QC splits and field duplicates were excluded from the screening data sets. Rejected results were excluded from the screening process. All analytes having at least one detected value were included in the data reduction process. Summary statistics calculated for each data aggregate included the minimum, maximum, and average (mean) detected values and the proportion of detected results to the total number of samples collected (Sections 4.2 and 4.4). For calculation of mean detected values, non-detected results were addressed by using one-half of the reported detection limit as a surrogate value during calculation of the mean result for each compound.

Following data reduction, the data were screened to identify SRCs using the processes outlined in the following sections. Additional screening of identified SRCs was conducted as part of the fate and transport evaluation to identify constituents of potential migration concern and as part of the risk assessments to identify human health and ecological COPCs (see Chapters 6.0 and 7.0).

4.1.3.2 Frequency of detection screen

For sample aggregates containing more than 20 samples, a frequency of detection criterion was applied to identify SRCs. Inorganic constituents, VOCs, SVOCs, pesticides, and PCBs with a frequency of detection greater than or equal to 5% (e.g., 1 in 20 samples) were carried forward to the facility-wide background screening and essential human nutrient screening steps, as applicable. If the frequency of detection for an analyte in one of these classes was less than 5%, a WOE approach was used to determine if the chemical was a SRC. The WOE approach involved examining the magnitude and locations of the detected results. If no clustering within a particular area was noted and concentrations were not substantially elevated relative to the detection limits, the detected results were considered spurious, and the compound was eliminated as a SRC. For sample populations comprised of less than 20 samples, all detected constituents were carried forward to the facility-wide background and essential human nutrient screening steps, as applicable.

All detected explosives and propellants were considered to be SRCs regardless of the frequency of detection and, thus, were subjected to the risk evaluations. However, the assessment of occurrence and distribution for those explosives and propellants having a frequency of detection less than 5% includes qualification that they were infrequently detected.

4.1.3.3 Facility-wide background screen

For each inorganic constituent passing the frequency of detection screen, concentrations were compared against established RVAAP facility-wide background values (Table 4-1). For inorganic constituents, if the maximum detected concentration (MDC) of an analyte exceeded its respective background criterion, it was considered to be a SRC. In the event a constituent was not detected in the background data set, the background value was set to zero, and any detected result for that constituent was considered above background. This conservative process ensured that detected constituents were not eliminated as SRCs simply because they were not detected in the background data set. All detected organic compounds were considered to be above background because these classes of compounds do not occur naturally.

4.1.3.4 Essential nutrients screen

Chemicals that are considered to be essential nutrients (calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the food supply and are often added to foods as supplements. Thus, these constituents are not generally addressed as SRCs in the contaminant nature and extent evaluation and in the risk evaluation (EPA 1989b and 1996b) unless they are grossly elevated relative to background values. The essential nutrient screen is not applied as part of the ecological risk evaluation. For the RQL Phase I RI, analyses were conducted for calcium, iron, magnesium, potassium, and sodium. These five constituents were eliminated as SRCs in all environmental media based on comparison to background values.

4.1.4 Data Presentation

Data summary statistics and screening results for SRCs in surface soil and groundwater at Ramsdell Quarry are presented in Sections 4-2 and 4-4. In the sections addressing the nature and extent of contamination for each media, analytical results for SRCs are presented in data summary tables whenever a sufficient number of detected values occurred to merit such tables. Selected constituents are presented in graphical format to depict spatial distribution (e.g., explosives/propellants and SVOCs). Where only a few detected values for a class of SRCs occurred, the values are addressed in the text of the chapter. Complete analytical results, including all non-detected results, are contained in Appendix G.

All identified SRCs are evaluated within the text of the contaminant occurrence and distribution sections below. However, certain SRCs are of specific interest and represent the focus of the assessment. The basis for identifying SRCs of specific interest involved several considerations. Those SRCs known to be related to historical operations (i.e., explosives and propellants) are highlighted. SRCs that were most frequently detected or at the highest concentrations above background also represent a focus for discussion. In addition, certain SRCs occurred at concentrations high enough to exceed risk-based screening criteria as presented in Chapter 5.0. Therefore, these constituents also are a focus for the evaluation. Because sampling depths were limited to 1 ft bgs or less, vertical profiles of contaminant distribution were not prepared.

4.1.5 Use of Previous Investigation Data

Sediment and surface water samples were collected and evaluated during the initial phase of the Groundwater Investigation and are presented in USACE 1999. Surface water samples were also collected during the second phase of the Groundwater Investigation, and are presented in USACE 2000. Sediment data from the initial phase of the Groundwater Investigation were included in the data sets for the human health (Chapter 6) and ecological (Chapter 7) risk assessments presented in this report as follows:

- Five samples from three sample locations were designated “dry” sediment locations (RQLsd-012, -013, and -019), because, at the time of sampling, those stations were dry, and have been incorporated into the surface soil (0 to 1.0 ft bgs) data set for the risk assessments. These data are also included in the surface soil section of Chapter 4, Nature and Extent.

- The remaining sediment samples from 0 to 0.5 ft bgs are considered to be “wet” or subaqueous sediments based on site conditions at the time of sampling (e.g., water depths were approximately 1 ft deep or greater at these locations) and are evaluated as sediments for human health and ecological receptors. Subaqueous sediment data from the USACE 1999 report were not duplicated in the nature and extent section of this current report but are summarized in Section 1.3.2.
- Surface water samples were included in both the human health and ecological risk assessments. Surface water results were not duplicated in the nature and extent section of this report, as they have been fully discussed in previous investigation reports (USACE 1999 and 2000), but the results are summarized in Section 1.3.2.

4.2 SURFACE SOIL DISCRETE SAMPLES

Surface soil samples were collected from ten discrete stations during the Phase I RI to: (1) assess contaminant occurrence and distribution, if any, in surface soil within the bottom of the quarry; and (2) undergo geotechnical analysis for total organic carbon. All discrete samples were analyzed for explosives, TAL metals, cyanide, and SVOCs; two discrete samples were analyzed for propellants; and one discrete sample was analyzed for VOCs and pesticides/PCBs. Five dry sediment samples from three locations from the initial phase of the Groundwater Investigation (USACE 1999) are also included in the surface soil data set, as described in Section 4.1.5. Data summary statistics and screening results to identify SRCs are presented in Table 4-2.

4.2.1 Explosives and Propellants

Table 4-2 contains summary statistics and results of the background comparison for explosive and propellant compounds. Ten explosives and propellants were detected in the RQL discrete surface soil and dry sediment samples. All detected explosives and propellants are considered SRCs regardless of their frequency of detection. Contaminants were detected at sites RQL-025, -026, -027 and -030 in the northern and western portions of the bottom of the quarry and sediment sample locations RQLsd-012, -013, and -019. These results are presented in Table 4-3 on a station-by-station basis. The distribution of detected explosives and propellants is shown on Figure 4-1.

Stations RQL-026 and -025, both located near the toe slope of RQL, contained the greatest numbers of detected explosive compounds with five identified SRCs at each station. Station RQL-026 had the overall highest concentrations of explosive compounds. One propellant compound, nitroglycerin, was detected at station RQL-025 at a concentration of 140 mg/kg.

4.2.2 Inorganics

Table 4-2 contains summary statistics and results of the background comparison for inorganic compounds (metals) in surface soil. There were 23 inorganic analytes detected in surface soil samples, 17 of which were identified as SRCs. Eight of the detected constituents were eliminated as potential surface soil SRCs because they were either considered essential nutrients (calcium, iron, magnesium, potassium, and sodium) or the concentration was less than background (aluminum, manganese, and vanadium). Three constituents were considered SRCs because no background data were available (cadmium, silver, and thallium).

Table 4-2. Summary of COPC Screening for Ramsdell Discrete Surface Soil and Dry Sediment Locations

Analyte	CAS Number	Units	Results >Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	95% UCL of Mean	Exposure Concentration	Site Background Criteria	Max Detect > Bkg	Site Related?
Explosives											
1,3-Dinitrobenzene	99-65-0	mg/kg	1/ 15	3.32E-01	3.90E+00	3.90E+00	7.81E-01	7.81E-01		Yes	Yes
2,4,6-Trinitrotoluene	118-96-7	mg/kg	3/15	3.33E-01	2.10E-02	4.00E+00	7.95E-01	7.95E-01		Yes	Yes
2,4-Dinitrotoluene	121-14-2	mg/kg	1/15	6.98E-02	4.70E-02	4.70E-02	8.55E-02	4.70E-02		Yes	Yes
2,6-Dinitrotoluene	606-20-2	mg/kg	1/15	6.18E-01	8.20E+00	8.20E+00	1.57E+00	1.57E+00		Yes	Yes
2-Amino-4,6-Dinitrotoluene	35572-78-2	mg/kg	2/10	9.46E-01	4.60E-01	8.60E+00	2.51E+00	2.51E+00		Yes	Yes
2-Nitrotoluene	88-72-2	mg/kg	1/15	1.05E-01	7.00E-02	7.00E-02	1.11E-01	7.00E-02		Yes	Yes
4-Amino-2,6-Dinitrotoluene	19406-51-0	mg/kg	2/10	1.81E-01	1.10E-01	1.30E+00	4.09E-01	4.09E-01		Yes	Yes
HMX	2691-41-0	mg/kg	5/15	1.93E-01	1.30E-01	6.80E-01	2.72E-01	2.72E-01		Yes	Yes
Nitroglycerin	55-63-0	mg/kg	1/ 7	2.16E+01	1.40E+02	1.40E+02	6.00E+01	6.00E+01		Yes	Yes
RDX	121-82-4	mg/kg	1/ 15	1.67E-01	3.50E-01	3.50E-01	2.07E-01	2.07E-01		Yes	Yes
Metals											
Aluminum	7429-90-5	mg/kg	15/15	1.06E+04	3.63E+03	2.21E+04	1.45E+04	1.45E+04	1.77E+04	Yes	Yes
Antimony	7440-36-0	mg/kg	11/15	2.16E+00	1.40E-01	1.64E+01	4.13E+00	4.13E+00	9.60E-01	Yes	Yes
Arsenic	7440-38-2	mg/kg	15/15	1.30E+01	8.70E+00	2.96E+01	1.53E+01	1.53E+01	1.54E+01	Yes	Yes
Barium	7440-39-3	mg/kg	15/15	9.35E+01	2.40E+01	2.68E+02	1.40E+02	1.40E+02	8.84E+01	Yes	Yes
Beryllium	7440-41-7	mg/kg	13/15	5.45E-01	2.50E-01	1.30E+00	6.69E-01	6.69E-01	8.80E-01	Yes	Yes
Cadmium	7440-43-9	mg/kg	10/15	1.18E+00	2.90E-01	4.70E+00	2.08E+00	2.08E+00		Yes	Yes
Calcium[b]	7440-70-2	mg/kg	15/15	5.34E+03	6.14E+02	2.87E+04	1.33E+04	1.33E+04	1.58E+04	Yes	No
Chromium	7440-47-3	mg/kg	15/15	3.06E+01	8.40E+00	2.00E+02	5.21E+01	5.21E+01	1.74E+01	Yes	Yes
Cobalt	7440-48-4	mg/kg	15/15	9.23E+00	4.50E+00	1.39E+01	1.05E+01	1.05E+01	1.04E+01	Yes	Yes
Copper	7440-50-8	mg/kg	15/15	5.74E+01	8.90E+00	3.50E+02	9.37E+01	9.37E+01	1.77E+01	Yes	Yes
Iron[b]	7439-89-6	mg/kg	15/15	2.65E+04	1.35E+04	7.30E+04	3.35E+04	3.35E+04	2.31E+04	Yes	No
Lead	7439-92-1	mg/kg	15/15	3.03E+02	1.43E+01	3.71E+03	7.33E+02	7.33E+02	2.61E+01	Yes	Yes
Magnesium[b]	7439-95-4	mg/kg	15/15	5.51E+03	9.14E+02	2.21E+04	9.79E+03	9.79E+03	3.03E+03	Yes	No
Manganese	7439-96-5	mg/kg	15/15	5.19E+02	1.62E+02	1.12E+03	7.68E+02	7.68E+02	1.45E+03	No	No
Mercury	7439-97-6	mg/kg	13/15	1.91E-01	3.00E-02	8.90E-01	7.90E-01	7.90E-01	3.60E-02	Yes	Yes
Nickel	7440-02-0	mg/kg	15/15	2.85E+01	1.14E+01	1.32E+02	4.18E+01	4.18E+01	2.11E+01	Yes	Yes
Potassium[b]	7440-09-7	mg/kg	15/15	1.21E+03	4.47E+02	3.30E+03	1.58E+03	1.58E+03	9.27E+02	Yes	No
Selenium	7782-49-2	mg/kg	2/15	7.85E-01	6.00E-01	2.00E+00	9.75E-01	9.75E-01	1.40E+00	Yes	Yes
Silver	7440-22-4	mg/kg	10/15	5.91E-01	6.40E-02	1.30E+00	1.67E+00	1.30E+00		Yes	Yes
Sodium[b]	7440-23-5	mg/kg	12/15	1.65E+02	1.58E+01	1.37E+02	3.89E+02	1.37E+02	1.23E+02	Yes	No

Table 4-2. Summary of COPC Screening for Ramsdell Discrete Surface Soil and Dry Sediment Locations (continued)

Analyte	CAS Number	Units	Results >Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	95% UCL of Mean	Exposure Concentration	Site Background Criteria	Max Detect > Bkg	Site Related?
Thallium	7440-28-0	mg/kg	2/15	2.81E-01	3.10E-01	6.20E-01	3.98E-01	3.98E-01		Yes	Yes
Vanadium	7440-62-2	mg/kg	15/15	1.98E+01	8.10E+00	4.07E+01	2.54E+01	2.54E+01	3.11E+01	Yes	Yes
Zinc	7440-66-6	mg/kg	15/15	2.17E+02	7.31E+01	7.37E+02	3.13E+02	3.13E+02	6.18E+01	Yes	Yes
Miscellaneous											
Total Organic Carbon	N997	%	10/10	4.87E-01	4.30E-01	5.70E-01	5.19E-01	5.19E-01		Yes	Yes
Organics-Semivolatile											
2-Methylnaphthalene	91-57-6	mg/kg	8/15	4.50E+00	6.70E-02	6.10E+01	1.16E+01	1.16E+01		Yes	Yes
Acenaphthene	83-32-9	mg/kg	5/15	2.43E+01	9.30E-02	3.60E+02	6.65E+01	6.65E+01		Yes	Yes
Acenaphthylene	208-96-8	mg/kg	2/15	5.74E-01	4.60E-02	4.30E+00	1.05E+00	1.05E+00		Yes	Yes
Anthracene	120-12-7	mg/kg	10/15	6.72E+01	6.80E-02	1.00E+03	1.85E+02	1.85E+02		Yes	Yes
Benz(*a*)anthracene	56-55-3	mg/kg	12/15	9.43E+01	1.80E-01	1.40E+03	2.59E+02	2.59E+02		Yes	Yes
Benzo(*a*)pyrene	50-32-8	mg/kg	12/15	6.48E+01	1.20E-01	9.60E+02	1.77E+02	1.77E+02		Yes	Yes
Benzo(*b*)fluoranthene	205-99-2	mg/kg	12/15	8.10E+01	2.00E-01	1.20E+03	2.22E+02	2.22E+02		Yes	Yes
Benzo(*g,h,i*)perylene	191-24-2	mg/kg	11/15	4.39E+01	9.70E-02	6.50E+02	1.20E+02	1.20E+02		Yes	Yes
Benzo(*k*)fluoranthene	207-08-9	mg/kg	11/15	3.91E+01	8.50E-02	5.80E+02	1.07E+02	1.07E+02		Yes	Yes
Bis(2-ethylhexyl)phthalate	117-81-7	mg/kg	6/15	2.04E+00	5.60E-02	2.10E-01	5.19E+00	2.10E-01		Yes	Yes
Carbazole	86-74-8	mg/kg	7/15	3.09E+01	5.80E-02	4.60E+02	8.49E+01	8.49E+01		Yes	Yes
Chrysene	218-01-9	mg/kg	12/15	6.76E+01	1.90E-01	1.00E+03	1.85E+02	1.85E+02		Yes	Yes
Dibenz(*a,h*)anthracene	53-70-3	mg/kg	3/15	1.23E+01	1.70E-01	1.80E+02	3.34E+01	3.34E+01		Yes	Yes
Dibenzofuran	132-64-9	mg/kg	6/15	1.83E+01	1.60E-01	2.70E+02	5.00E+01	5.00E+01		Yes	Yes
Fluoranthene	206-44-0	mg/kg	13/15	2.09E+02	6.70E-02	3.10E+03	5.72E+02	5.72E+02		Yes	Yes
Fluorene	86-73-7	mg/kg	5/15	3.03E+01	9.10E-02	4.50E+02	8.31E+01	8.31E+01		Yes	Yes
Indeno(1,2,3-*cd*)pyrene	193-39-5	mg/kg	12/15	4.25E+01	4.60E-02	6.30E+02	1.16E+02	1.16E+02		Yes	Yes
Naphthalene	91-20-3	mg/kg	6/15	7.04E+00	9.50E-02	1.00E+02	1.87E+01	1.87E+01		Yes	Yes
Phenanthrene	85-01-8	mg/kg	12/15	2.15E+02	2.30E-01	3.20E+03	5.91E+02	5.91E+02		Yes	Yes
Pyrene	129-00-0	mg/kg	13/15	2.02E+02	5.30E-02	3.00E+03	5.54E+02	5.54E+02		Yes	Yes
Organics-Volatile											
2-Butanone	78-93-3	mg/kg	2/6	1.63E-02	6.50E-03	3.50E-02	2.44E-02	2.44E-02		Yes	Yes
Acetone	67-64-1	mg/kg	3/6	2.71E-02	3.70E-03	9.80E-02	3.04E-01	9.80E-02		Yes	Yes
Methylene Chloride	75-09-2	mg/kg	1/6	4.76E-03	7.30E-04	7.30E-04	7.12E-03	7.30E-04		Yes	Yes

[a] Values less than detection were set to one-half of the reporting limit in calculation of the average.

[b] Eliminated as an SRC is based on the essential element screen.

CAS = Chemical Abstracts Service.

COPC = Constituent of potential concern.

HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrarzocine.

RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.

UCL95 = 95% upper confidence limit.

Table 4-3. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Explosives

Location		**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**RQL Dry Sediment**	**RQL Dry Sediment**	**RQL Dry Sediment**
Station		**RQL-025**	**RQL-026**	**RQL-027**	**RQL-030**	**RQLsd-012**	**RQLsd-013**	**RQLsd-019**
Sample ID		**RQ0125**	**RQ0126**	**RQ0127**	**RQ0130**	**RQ0023**	**RQ0032**	**RQ0029**
Customer ID		**RQLss-025-0125-SO**	**RQLss-026-0126-SO**	**RQLss-027-0127-SO**	**RQLss-030-0130-SO**	**RQLsd-012-0023-SD**	**RQLsd-013-0032-SD**	**RQLsd-019-0029-SD**
Date		**11/03/2003**	**11/04/2003**	**11/04/2003**	**11/04/2003**	**07/08/1998**	**07/08/1998**	**07/08/1998**
Depth (ft)		**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**
Filtered		**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Explosives								
Analyte (mg/kg)	**Units**							
1,3-Dinitrobenzene	mg/kg		3.9 =					
2,4,6-Trinitrotoluene	mg/kg		4 =		0.08 J	0.021 J		
2,4-Dinitrotoluene	mg/kg							0.047 J
2,6-Dinitrotoluene	mg/kg		8.2 =					
2-Amino-4,6-dinitrotoluene	mg/kg		8.6 =		0.46 =			
2-Nitrotoluene	mg/kg						0.07 J	
4-Amino-2,6-dinitrotoluene	mg/kg		1.3 =		0.11 =			
4-Nitrotoluene	mg/kg							
HMX	mg/kg			0.51 =	0.68 =	0.13 J	0.15 J	0.13 J
Nitroglycerin	mg/kg	140 =						
RDX	mg/kg				0.35 =			

HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
RQL = Ramsdell Quarry Landfill.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
"=" = Analyte present and concentration accurate.
J = Estimated value less than reporting limits.
Blank cells represent non-detect values.

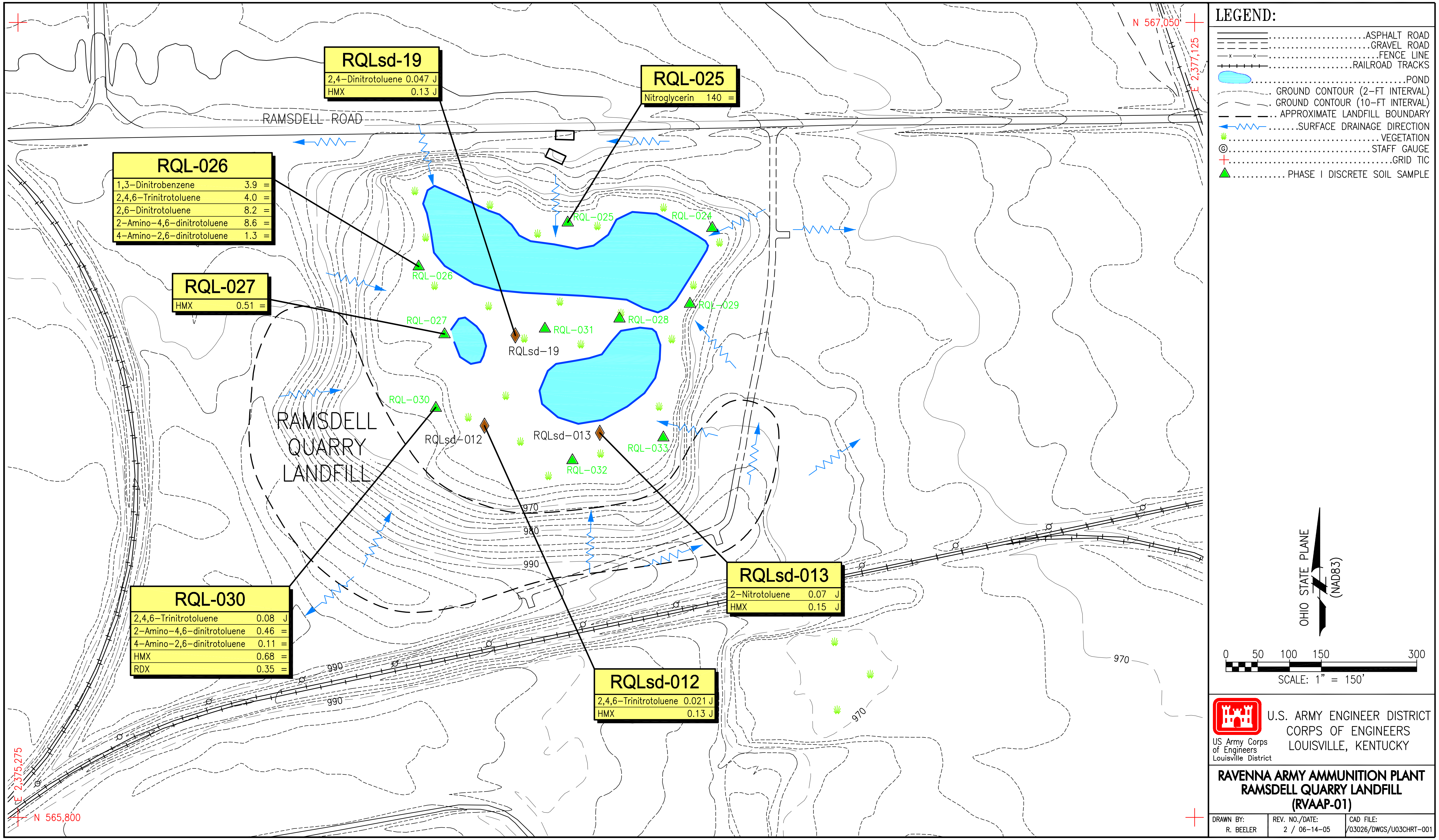

Figure 4-1. Detected Explosives and Propellants in Surface Soil (mg/kg)

Barium, cobalt, and nickel were detected at all sites and exceeded their respective background values in 30 to 40% of the samples. Chromium, copper, lead, and mercury were also detected at every site and were above background in 70 to 90% of the samples. The most pervasive constituent was zinc, which was detected at all sites at concentrations greater than background. Arsenic and beryllium were detected at nearly all sites, but only exceeded background concentrations in 10% of the samples.

Station RQL-026 in the northwest area of the quarry bottom at the base of the toe slope of the landfill had the highest number of metals that exceeded background concentrations (16). The stations with the lowest number of metals that exceeded background concentrations were RQL-025 (four inorganic SRCs) in the northern portion of the quarry bottom, RQL-032 (five inorganic SRCs) in the southern portion of the quarry bottom, and sediment locations RQLsd-019 (five organic SRCs) located in the middle of the quarry bottom.

The discussion below contains a brief summary of the nature and extent for each of the nine inorganic SRCs that exceeded background concentrations and were identified as the most pervasive across the site. Results by sampling stations are presented in Table 4-4.

- Antimony and barium were not concentrated in any specific area of the landfill. Antimony was detected above the background criterion in four samples, and barium was detected above the background criterion in six samples. The maximum concentration for both was found at RQL-026 (16.4 and 268 mg/kg, respectively). Elevated concentrations of antimony were noted at RQL-028 (2.6 mg/kg) and RQL-029 (7.2 mg/kg). Elevated concentrations of barium were also observed at RQL-024 (131 mg/kg), RQL-29 (150 mg/kg), RQL-030 (126 mg/kg), and RQLsd-013 (118 mg/kg).

- Chromium and copper were detected above background throughout the area of the quarry bottom. Chromium was detected above the background criterion in seven samples and copper was detected above the background criterion in nine samples. The highest concentrations for both inorganics were found at RQL-028 (200 and 350 mg/kg, respectively).

- Cobalt was detected above background concentrations in five samples, but was not concentrated in any specific area of the landfill. The maximum concentration was found at RQLsd-019 (13.9 mg/kg).

- Lead was detected throughout the quarry bottom above the background criterion in 12 samples. The highest concentration was detected at RQL-026 (3,710 mg/kg).

- Mercury was detected above the background criterion in 11 samples. The highest concentrations were in the northeast portion of the quarry bottom (RQL-029 at 0.78 mg/kg and RQL-024 at 0.34 mg/kg), and the sediment samples from RQLsd-012 (0.89 mg/kg).

- Nickel was detected above background concentrations in six samples, but was not concentrated in any specific area of the quarry bottom. The highest concentration was found at RQL-028 (132 mg/kg).

- Zinc exceeded background concentrations at all sampling stations. The highest concentrations were found at RQL-026 (688 mg/kg) and RQL-028 (737 mg/kg).

Table 4-4. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Inorganics

Location			**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**
Station			**RQL-024**	**RQL-025**	**RQL-026**	**RQL-027**	**RQL-028**
Sample ID			**RQ0124**	**RQ0125**	**RQ0126**	**RQ0127**	**RQ0128**
Customer ID			**RQLss-024-0124-SO**	**RQLss-025-0125-SO**	**RQLss-026-0126-SO**	**RQLss-027-0127-SO**	**RQLss-028-0128-SO**
Date			**11/03/2003**	**11/03/2003**	**11/04/2003**	**11/04/2003**	**11/04/2003**
Depth (ft)			**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**
Filtered			**Total**	**Total**	**Total**	**Total**	**Total**
Field Type			**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte (mg/kg)	**Units**	**Bkg. Criteria**					
Inorganics							
Aluminum	mg/kg	17,700	13,100 =	3,630 =	13,100 =	11,100 =	8,430 =
Antimony	mg/kg	0.96	0.52 J	0.23 J	16.4 J *	0.6 J	2.6 J *
Arsenic	mg/kg	15.4	8.7 =	29.6 = *	12.4 =	10.7 =	14.3 =
Barium	mg/kg	88.4	131 J *	24 J	268 J *	75.9 J	78.7 J
Beryllium	mg/kg	0.88	0.65 =	0.25 =	1.3 = *	0.53 =	0.52 =
Cadmium	mg/kg	0	0.7 = *	0.29 = *	2.7 = *	3 = *	4.7 = *
Calcium	mg/kg	15,800	3,980 =	638 =	28,700 = *	2,160 =	4,220 =
Chromium	mg/kg	17.4	18 = *	8.4 =	36.2 = *	21.3 = *	200 = *
Cobalt	mg/kg	10.4	10 =	4.5 =	7.9 =	9.2 =	9.6 =
Copper	mg/kg	17.7	27 = *	8.9 =	81.6 = *	29 = *	350 = *
Iron	mg/kg	23,100	20,200 =	13,500 =	73,000 = *	19,200 =	44,000 = *
Lead	mg/kg	26.1	69.3 J *	24.8 J	3,710 J *	52.2 J *	177 J *
Magnesium	mg/kg	3,030	2,480 J	914 J	7,980 J *	3,230 J *	6,920 J *
Manganese	mg/kg	1,450	596 =	162 =	1,120 =	323 =	349 =
Mercury	mg/kg	0.036	0.34 = *	0.03 J	0.13 = *	0.039 J *	0.099 = *
Nickel	mg/kg	21.1	16.4 =	11.4 =	34.7 = *	19.6 =	132 = *
Potassium	mg/kg	927	1,200 J *	726 J	1,170 J *	1,140 J *	1,040 J *
Selenium	mg/kg	1.4					
Silver	mg/kg	0	0.19 = *	0.064 J *	0.98 = *	0.19 = *	1.3 = *
Sodium	mg/kg	123	40 =	15.8 J	112 =	36 =	73.4 =
Thallium	mg/kg	0	0.31 J *		0.62 J *		
Vanadium	mg/kg	31.1	22.1 =	8.1 =	17.3 =	20.8 =	24.2 =
Zinc	mg/kg	61.8	145 = *	73.1 = *	688 = *	126 = *	737 = *

Table 4-4. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Inorganics (continued)

Location			Discrete Surface Soil Locations	Discrete Surface Soil Locations	Discrete Surface Soil Locations	Discrete Surface Soil Locations	Discrete Surface Soil Locations
Station			RQL-029	RQL-030	RQL-031	RQL-032	RQL-033
Sample ID			RQ0129	RQ0130	RQ0131	RQ0132	RQ0133
Customer ID			RQLss-029-0129-SO	RQLss-030-0130-SO	RQLss-031-0131-SO	RQLss-032-0132-SO	RQLss-033-0133-SO
Date			11/04/2003	11/04/2003	11/04/2003	11/04/2003	11/04/2003
Depth (ft)			0 to 1	0 to 1	0 to 1	0 to 1	0 to 1
Filtered			Total	Total	Total	Total	Total
Field Type			Grab	Grab	Grab	Grab	Grab
Analyte (mg/kg)	Units	Bkg. Criteria					
Inorganics							
Aluminum	mg/kg	17,700	17,000 =	13,800 =	10,900 =	5,710 =	12,000 =
Antimony	mg/kg	0.96	7.2 J *	0.49 J	0.21 J	0.14 J	0.38 J
Arsenic	mg/kg	15.4	11.2 =	13.4 =	9.5 =	10 =	11.1 =
Barium	mg/kg	88.4	150 J *	126 J *	63.5 J	57.5 J	72.5 J
Beryllium	mg/kg	0.88	0.76 =	0.73 =	0.53 =	0.45 =	0.56 =
Cadmium	mg/kg	0	1.2 = *	0.84 = *	0.56 = *	0.53 = *	0.61 = *
Calcium	mg/kg	15,800	1,130 =	5,930 =	2,380 =	2,060 =	2,350 =
Chromium	mg/kg	17.4	24.3 = *	21.3 = *	15.9 =	16.5 =	17.5 = *
Cobalt	mg/kg	10.4	13.1 = *	11.1 = *	12.9 = *	6.2 =	8.2 =
Copper	mg/kg	17.7	44.3 = *	55.7 = *	22.6 = *	44.9 = *	18.9 = *
Iron	mg/kg	23,100	25,000 = *	29,200 = *	29,200 = *	19,000 =	20,100 =
Lead	mg/kg	26.1	218 J *	73.8 J *	27.4 J *	14.3 J	29.8 J *
Magnesium	mg/kg	3,030	2,610 J	5,580 J *	3,470 J *	3,370 J *	2,730 J
Manganese	mg/kg	1,450	469 =	944 =	488 =	379 =	288 =
Mercury	mg/kg	0.036	0.78 = *	0.051 J *			0.13 = *
Nickel	mg/kg	21.1	20.5 =	19.6 =	28.3 = *	16.5 =	19.9 =
Potassium	mg/kg	927	1,400 J *	1,290 J *	1,260 J *	620 J	1,690 J *
Selenium	mg/kg	1.4					
Silver	mg/kg	0	0.36 = *	0.41 = *	0.2 = *	0.1 J *	0.07 J *
Sodium	mg/kg	123	34 =	77.7 =	38.7 =	69.8 =	41.3 =
Thallium	mg/kg	0					
Vanadium	mg/kg	31.1	30.1 =	26.1 =	18.6 =	16.4 =	18.9 =
Zinc	mg/kg	61.8	328 = *	169 = *	79.9 = *	81.3 = *	104 = *

Table 4-4. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Inorganics (continued)

Location			RQL Dry Sediment	RQL Dry Sediment	RQL Dry Sediment	RQL Dry Sediment	RQL Dry Sediment
Station			RQLsd-012	RQLsd-012	RQLsd-013	RQLsd-013	RQLsd-019
Sample ID			RQ0023	RQ0064	RQ0032	RQ0033	RQ0029
Customer ID			RQLsd-012-0023-SD	RQLsd-012-0064-SD	RQLsd-013-0032-SD	RQLsd-013-0033-SD	RQLsd-019-0029-SD
Date			07/08/1998	07/27/1998	07/08/1998	07/08/1998	07/08/1998
Depth (ft)			0 to 1	0 to 0	0 to 1	1 to 1	0 to 1
Filtered			Total	Total	Total	Total	Total
Field Type			Grab	Grab	Grab	Grab	Grab
Analyte (mg/kg) Inorganics	Units	Bkg. Criteria					
Aluminum	mg/kg	17,700	8,460 =	9,300 =	22,100 = *	4,300 =	5,560 =
Antimony	mg/kg	0.96		1.9 J *			
Arsenic	mg/kg	15.4	11 =	12.6 =	15.2 =	13.4 =	12.3 =
Barium	mg/kg	88.4	77.3 =	91.8 = *	118 = *	33 J	35.9 =
Beryllium	mg/kg	0.88	0.38 J	0.34 J	0.59 J		
Cadmium	mg/kg	0					
Calcium	mg/kg	15,800	12,200 J	11,000 =	1,530 J	1,270 J	614 J
Chromium	mg/kg	17.4	14.7 =	17.3 =	29.1 = *	8.7 =	9 =
Cobalt	mg/kg	10.4	7.1 =	8.9 =	10.8 J *	5 J	13.9 = *
Copper	mg/kg	17.7	48.2 = *	48.8 = *	41.1 = *	19.5 = *	20.7 = *
Iron	mg/kg	23,100	21,200 =	25,400 = *	28,600 = *	13,700 =	16,800 =
Lead	mg/kg	26.1	27.1 = *	36.3 = *	38.4 = *	21.1 =	26.7 = *
Magnesium	mg/kg	3,030	22,100 J *	13,100 = *	4,660 J *	2,180 J	1,300 J
Manganese	mg/kg	1,450	829 J	1,000 =	223 J	432 J	189 J
Mercury	mg/kg	0.036	0.89 J *	0.12 J *	0.15 J *	0.048 J *	0.033 J
Nickel	mg/kg	21.1	15.3 =	21.5 = *	30.1 = *	12.8 =	28.4 = *
Potassium	mg/kg	927	895 J	1,320 = *	3,300 J *	713 J	447 J
Selenium	mg/kg	1.4			2 = *		0.6 =
Silver	mg/kg	0					
Sodium	mg/kg	123	137 J *	73.3 J			
Thallium	mg/kg	0					
Vanadium	mg/kg	31.1	14.4 =	19.2 =	40.7 = *	9 J	10.5 =
Zinc	mg/kg	61.8	100 = *	147 = *	214 = *	135 = *	124 = *

* = Value above facility-wide background criterion.
"=" = Analyte present and concentration accurate.
Blank cells represent non-detect values.
J = Estimated value less than reporting limits.
RQL = Ramsdell Quarry Landfill.

- Cadmium (10 of 15 detections), silver (10 of 15 detections), and thallium (2 of 15 detections) were not detected in background samples from the WBG Phase II RI. Cadmium concentrations ranged from 0.29 to 4.7 mg/kg and silver concentrations ranged from 0.064 to 1.3 mg/kg. The highest concentrations for both of these SRCs were found at RQL-028. The two thallium detections were found at RQL-024 (0.31 mg/kg) and RQL-026 (0.62 mg/kg). These metals were not detected in the dry sediment samples.

4.2.3 Semivolatile Organic Compounds

Table 4-2 contains summary statistics and results of the background comparison for SVOCs in discrete surface soil samples. There were 20 SVOCs detected in the discrete surface soil and dry sediment samples and SVOCs were detected at all sampling stations except RQLsd-013. RQLsd-019 had only two SVOCs detected (fluoranthene and pyrene). All SVOCs were detected in over 5% of the samples and are considered SRCs because background criteria are zero for organic compounds. There were eight SVOCs detected at nearly all sampling stations: benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-*cd*)pyrene, phenanthrene, and pyrene. The greatest numbers and concentrations of SVOCs were detected at RQL-026 (19 SVOCs), RQL-027 (18 SVOCs), RQL-030 (19 SVOCs), and RQLsd-012 (17 SVOCs) along the base of the toe slope of the landfill. Three of the least frequently detected SVOCs, acenaphthylene, acenaphthene, and fluorene, were also generally restricted to this area. Acenaphthene and fluorene were also found near this area north of the pond at RQL-025. Summary results are presented in Table 4-5 on a station-by-station basis. The distribution of detected SVOCs is shown on Figure 4-2.

The MDCs for nearly all SVOCs were observed at RQL-026 in the northwest corner of the area. Only bis(2-ethylhexyl)phthalate was not detected at this site. Site RQL-025 north of the pond also had high concentrations of many PAHs (range 0.63 to 19 mg/kg) but PAHs were relatively high (greater than 0.1 mg/kg) at all sites.

4.2.4 Volatile Organic Compounds, Pesticides, and Polychlorinated Biphenyls

VOCs, pesticides, and PCBs were only analyzed for in the discrete surface soil sample collected at RQL-024. No VOCs, pesticides, or PCBs were detected. The VOCs 2-butanone, acetone, and methylene chloride were each detected in at least one of the dry sediment samples.

4.2.5 Miscellaneous

Table 4-1 contains summary statistics and results for total organic carbon analyses in discrete surface soil samples. Total organic carbon was detected at all sites at levels ranging from 0.43 to 0.57%.

4.2.6 Summary of Surface Soil Discrete Samples

- Ten explosives and propellants were detected in discrete surface soil samples and were identified as SRCs. The majority of detected explosives occurred along the western portion of the quarry bottom along the base of the toe slope of the landfill.

- Seventeen inorganic analytes were identified as SRCs. Barium, cobalt, and nickel were detected at all sites and exceeded background concentrations in 30 to 40% of the samples. Chromium, copper, lead, and mercury were also detected at every station and were above

Table 4-5. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Organic Semivolatiles

Location		**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**
Station		**RQL-024**	**RQL-025**	**RQL-026**	**RQL-027**	**RQL-028**	**RQL-029**
Sample ID		**RQ0124**	**RQ0125**	**RQ0126**	**RQ0127**	**RQ0128**	**RQ0129**
Customer ID		**RQLss-024-0124-SO**	**RQLss-025-0125-SO**	**RQLss-026-0126-SO**	**RQLss-027-0127-SO**	**RQLss-028-0128-SO**	**RQLss-029-0129-SO**
Date		**11/03/2003**	**11/03/2003**	**11/04/2003**	**11/04/2003**	**11/04/2003**	**11/04/2003**
Depth (ft)		**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**
Filtered		**Total**	**Total**	**Total**	**Total**	**Total**	**Total**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte (mg/kg)	**Units**						
Semivolatile Organics							
2-Methylnaphthalene	mg/kg	0.072 J	2 U	61 =	0.42 J	0.12 J	
Acenaphthene	mg/kg		0.63 J	360 =	0.093 J		
Acenaphthylene	mg/kg			4.3 J			
Anthracene	mg/kg		4 =	1,000 =	0.17 J	0.33 J	0.11 J
Benz(*a*)anthracene	mg/kg	0.26 J	9.3 =	1,400 J	0.38 J	1 J	0.29 J
Benzo(*a*)pyrene	mg/kg	0.22 J	6.8 =	960 =	0.3 J	0.7 J	0.23 J
Benzo(*b*)fluoranthene	mg/kg	0.28 J	8.3 =	1,200 =	0.5 =	1 J	0.36 J
Benzo(*g,h,i*)perylene	mg/kg	0.17 J	3.9 =	650 =	0.2 J	0.64 J	0.17 J
Benzo(*k*)fluoranthene	mg/kg	0.13 J	3.1 =	580 =	0.13 J	0.31 J	0.11 J
Bis(2-ethylhexyl)phthalate	mg/kg	0.066 J			0.079 J	0.21 J	
Carbazole	mg/kg		0.82 J	460 =	0.11 J	0.08 J	0.058 J
Chrysene	mg/kg	0.25 J	8 =	1,000 J	0.41 J	0.86 J	0.28 J
Dibenz(*a,h*)anthracene	mg/kg			180 =		0.17 J	
Dibenzofuran	mg/kg		0.58 J	270 =	0.16 J		
Fluoranthene	mg/kg	0.62 =	19 =	3,100 =	0.91 =	1.5 J	0.62 =
Fluorene	mg/kg		1 J	450 =	0.091 J		
Indeno(1,2,3-*cd*)pyrene	mg/kg	0.15 J	3.6 =	630 =	0.17 J	0.51 J	0.14 J
Naphthalene	mg/kg			100 =	0.24 J	0.095 J	
Phenanthrene	mg/kg	0.38 J	15 =	3,200 =	0.91 =	1.1 J	0.48 =
Pyrene	mg/kg	0.41 J	17 =	3,000 J	0.83 =	1.8 J	0.49 =

Table 4-5. Results for Analytes Detected in Discrete Surface Soil and RQL Dry Sediment Locations – Organic Semivolatiles (continued)

Location		**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**Discrete Surface Soil Locations**	**RQL Dry Sediment**	**RQL Dry Sediment**	**RQL Dry Sediment**
Station		**RQL-030**	**RQL-031**	**RQL-032**	**RQL-033**	**RQLsd-012**	**RQLsd-012**	**RQLsd-019**
Sample ID		**RQ0130**	**RQ0131**	**RQ0132**	**RQ0133**	**RQ0023**	**RQ0064**	**RQ0029**
Customer ID		**RQLss-030-0130-SO**	**RQLss-031-0131-SO**	**RQLss-032-0132-SO**	**RQLss-033-0133-SO**	**RQLsd-012-0023-SD**	**RQLsd-012-0064-SD**	**RQLsd-019-0029-SD**
Date		**11/04/2003**	**11/04/2003**	**11/04/2003**	**11/04/2003**	**07/08/1998**	**07/27/1998**	**07/08/1998**
Depth (ft)		**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 1**	**0 to 0**	**0 to 1**
Filtered		**Total**	**Total**	**Total**	**Total**	**Total**	**Total**	**Total**
Field Type		**Grab**	**Grab**	**Grab**	**Grab**	**Grab**	**Grab**	**Grab**
Analyte (mg/kg)	**Units**							
Semivolatile Organics								
2-Methylnaphthalene	mg/kg	1.4 =		1.5 =	0.067 J	0.11 J		
Acenaphthene	mg/kg	0.1 J				0.34 J		
Acenaphthylene	mg/kg	0.046 J						
Anthracene	mg/kg	0.19 J	0.074 J		0.12 J	0.71 =	0.068 J	
Benz(*a*)anthracene	mg/kg	0.43 =	0.24 J	0.25 J	0.96 =	0.69 =	0.18 J	
Benzo(*a*)pyrene	mg/kg	0.29 J	0.17 J	0.12 J	0.83 =	0.51 =	0.19 J	
Benzo(*b*)fluoranthene	mg/kg	0.47 =	0.27 J	0.2 J	1.7 =	0.58 =	0.25 J	
Benzo(*g,h,i*)perylene	mg/kg	0.19 J	0.12 J		0.82 =	0.23 J	0.097 J	
Benzo(*k*)fluoranthene	mg/kg	0.13 J	0.085 J		0.53 =	0.25 J	0.11 J	
Bis(2-ethylhexyl)phthalate	mg/kg	0.056 J	0.073 J		0.063 J			
Carbazole	mg/kg	0.1 J				0.41 J		
Chrysene	mg/kg	0.46 =	0.24 J	0.26 J	1.1 =	0.59 =	0.19 J	
Dibenz(*a,h*)anthracene	mg/kg				0.25 J			
Dibenzofuran	mg/kg	0.42 J		0.46 J		0.24 J		
Fluoranthene	mg/kg	1.1 =	0.45 =	0.67 =	0.72 =	1.8 =	0.38 J	0.067 J
Fluorene	mg/kg	0.1 J				0.39 J		
Indeno(1,2,3-*cd*)pyrene	mg/kg	0.15 J	0.091 J	0.046 J	0.74 =	0.27 J	0.1 J	
Naphthalene	mg/kg	0.91 =		0.98 =		0.1 J		
Phenanthrene	mg/kg	1.5 =	0.34 J	0.9 =	0.25 J	2 =	0.23 J	
Pyrene	mg/kg	0.91 =	0.42 J	0.48 =	0.78 =	1.2 J	0.31 J	0.053 J

"=" = Analyte present and concentration accurate.
J = Estimated value less than reporting limits.
Blank cells represent non-detect values.
RQL = Ramsdell Quarry Landfill.

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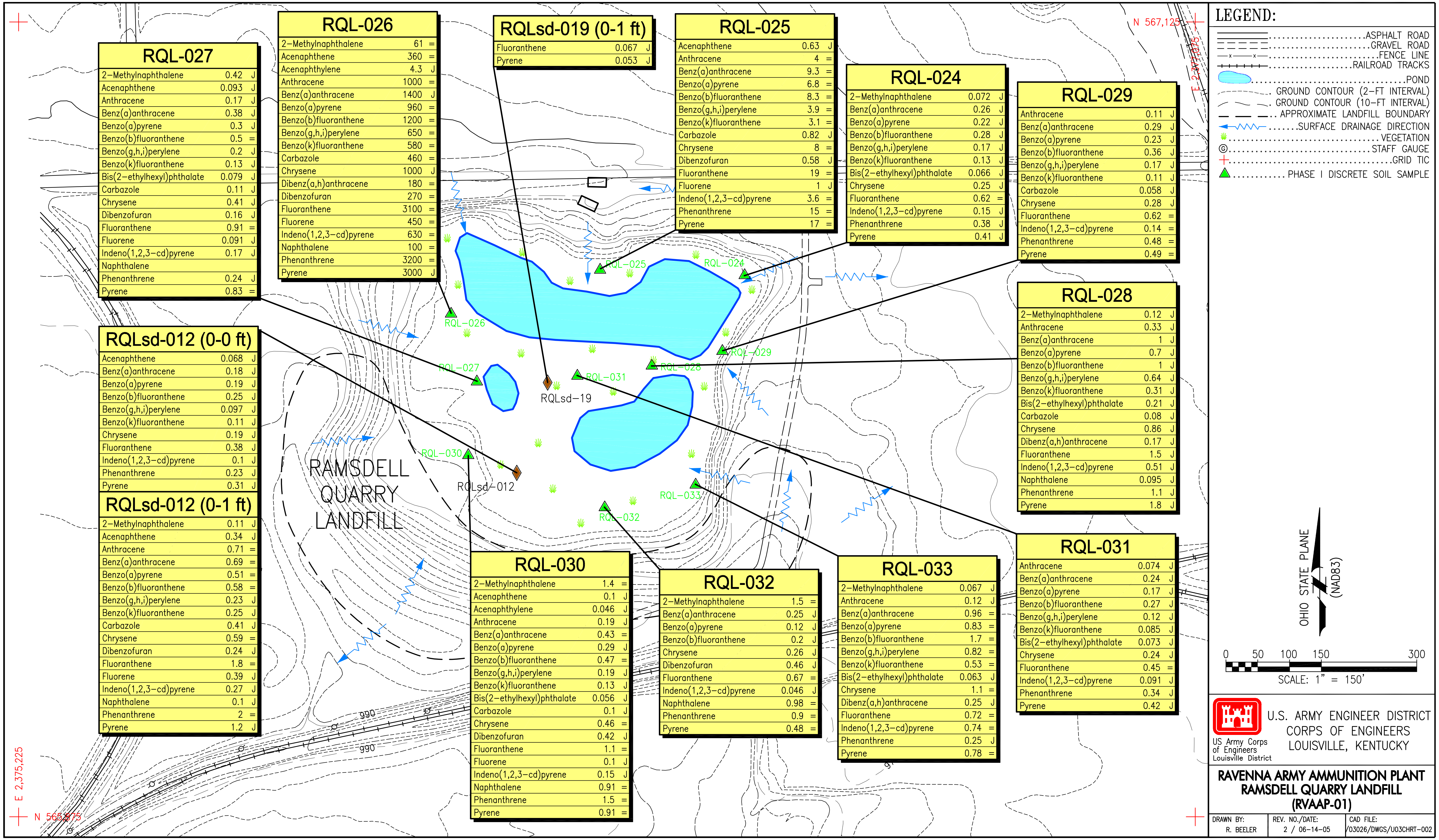

RQL-027

2–Methylnaphthalene	0.42	J
Acenaphthene	0.093	J
Anthracene	0.17	J
Benz(a)anthracene	0.38	J
Benzo(a)pyrene	0.3	J
Benzo(b)fluoranthene	0.5	=
Benzo(g,h,i)perylene	0.2	J
Benzo(k)fluoranthene	0.13	J
Bis(2–ethylhexyl)phthalate	0.079	J
Carbazole	0.11	J
Chrysene	0.41	J
Dibenzofuran	0.16	J
Fluoranthene	0.91	=
Fluorene	0.091	J
Indeno(1,2,3–cd)pyrene	0.17	J
Naphthalene		
Phenanthrene	0.24	J
Pyrene	0.83	=

RQL-026

2–Methylnaphthalene	61	=
Acenaphthene	360	=
Acenaphthylene	4.3	J
Anthracene	1000	=
Benz(a)anthracene	1400	J
Benzo(a)pyrene	960	=
Benzo(b)fluoranthene	1200	=
Benzo(g,h,i)perylene	650	=
Benzo(k)fluoranthene	580	=
Carbazole	460	=
Chrysene	1000	J
Dibenz(a,h)anthracene	180	=
Dibenzofuran	270	=
Fluoranthene	3100	=
Fluorene	450	=
Indeno(1,2,3–cd)pyrene	630	=
Naphthalene	100	=
Phenanthrene	3200	=
Pyrene	3000	J

RQLsd-019 (0-1 ft)

Fluoranthene	0.067	J
Pyrene	0.053	J

RQL-025

Acenaphthene	0.63	J
Anthracene	4	=
Benz(a)anthracene	9.3	=
Benzo(a)pyrene	6.8	=
Benzo(b)fluoranthene	8.3	=
Benzo(g,h,i)perylene	3.9	=
Benzo(k)fluoranthene	3.1	=
Carbazole	0.82	J
Chrysene	8	=
Dibenzofuran	0.58	J
Fluoranthene	19	=
Fluorene	1	J
Indeno(1,2,3–cd)pyrene	3.6	=
Phenanthrene	15	=
Pyrene	17	=

RQL-024

2–Methylnaphthalene	0.072	J
Benz(a)anthracene	0.26	J
Benzo(a)pyrene	0.22	J
Benzo(b)fluoranthene	0.28	J
Benzo(g,h,i)perylene	0.17	J
Benzo(k)fluoranthene	0.13	J
Bis(2–ethylhexyl)phthalate	0.066	J
Chrysene	0.25	J
Fluoranthene	0.62	=
Indeno(1,2,3–cd)pyrene	0.15	J
Phenanthrene	0.38	J
Pyrene	0.41	J

RQL-029

Anthracene	0.11	J
Benz(a)anthracene	0.29	J
Benzo(a)pyrene	0.23	J
Benzo(b)fluoranthene	0.36	J
Benzo(g,h,i)perylene	0.17	J
Benzo(k)fluoranthene	0.11	J
Carbazole	0.058	J
Chrysene	0.28	J
Fluoranthene	0.62	=
Indeno(1,2,3–cd)pyrene	0.14	=
Phenanthrene	0.48	=
Pyrene	0.49	=

RQL-028

2–Methylnaphthalene	0.12	J
Anthracene	0.33	J
Benz(a)anthracene	1	J
Benzo(a)pyrene	0.7	J
Benzo(b)fluoranthene	1	J
Benzo(g,h,i)perylene	0.64	J
Benzo(k)fluoranthene	0.31	J
Bis(2–ethylhexyl)phthalate	0.21	J
Carbazole	0.08	J
Chrysene	0.86	J
Dibenz(a,h)anthracene	0.17	J
Fluoranthene	1.5	J
Indeno(1,2,3–cd)pyrene	0.51	J
Naphthalene	0.095	J
Phenanthrene	1.1	J
Pyrene	1.8	J

RQLsd-012 (0-0 ft)

Acenaphthene	0.068	J
Benz(a)anthracene	0.18	J
Benzo(a)pyrene	0.19	J
Benzo(b)fluoranthene	0.25	J
Benzo(g,h,i)perylene	0.097	J
Benzo(k)fluoranthene	0.11	J
Chrysene	0.19	J
Fluoranthene	0.38	J
Indeno(1,2,3–cd)pyrene	0.1	J
Phenanthrene	0.23	J
Pyrene	0.31	J

RQLsd-012 (0-1 ft)

2–Methylnaphthalene	0.11	J
Acenaphthene	0.34	J
Anthracene	0.71	=
Benz(a)anthracene	0.69	=
Benzo(a)pyrene	0.51	=
Benzo(b)fluoranthene	0.58	=
Benzo(g,h,i)perylene	0.23	J
Benzo(k)fluoranthene	0.25	J
Carbazole	0.41	J
Chrysene	0.59	=
Dibenzofuran	0.24	J
Fluoranthene	1.8	=
Fluorene	0.39	J
Indeno(1,2,3–cd)pyrene	0.27	J
Naphthalene	0.1	J
Phenanthrene	2	=
Pyrene	1.2	J

RQL-030

2–Methylnaphthalene	1.4	=
Acenaphthene	0.1	J
Acenaphthylene	0.046	J
Anthracene	0.19	J
Benz(a)anthracene	0.43	=
Benzo(a)pyrene	0.29	J
Benzo(b)fluoranthene	0.47	=
Benzo(g,h,i)perylene	0.19	J
Benzo(k)fluoranthene	0.13	J
Bis(2–ethylhexyl)phthalate	0.056	J
Carbazole	0.1	J
Chrysene	0.46	=
Dibenzofuran	0.42	J
Fluoranthene	1.1	=
Fluorene	0.1	J
Indeno(1,2,3–cd)pyrene	0.15	J
Naphthalene	0.91	=
Phenanthrene	1.5	=
Pyrene	0.91	=

RQL-032

2–Methylnaphthalene	1.5	=
Benz(a)anthracene	0.25	J
Benzo(a)pyrene	0.12	J
Benzo(b)fluoranthene	0.2	J
Chrysene	0.26	J
Dibenzofuran	0.46	J
Fluoranthene	0.67	=
Indeno(1,2,3–cd)pyrene	0.046	J
Naphthalene	0.98	=
Phenanthrene	0.9	=
Pyrene	0.48	=

RQL-033

2–Methylnaphthalene	0.067	J
Anthracene	0.12	J
Benz(a)anthracene	0.96	=
Benzo(a)pyrene	0.83	=
Benzo(b)fluoranthene	1.7	=
Benzo(g,h,i)perylene	0.82	=
Benzo(k)fluoranthene	0.53	=
Bis(2–ethylhexyl)phthalate	0.063	J
Chrysene	1.1	=
Dibenz(a,h)anthracene	0.25	J
Fluoranthene	0.72	=
Indeno(1,2,3–cd)pyrene	0.74	=
Phenanthrene	0.25	J
Pyrene	0.78	=

RQL-031

Anthracene	0.074	J
Benz(a)anthracene	0.24	J
Benzo(a)pyrene	0.17	J
Benzo(b)fluoranthene	0.27	J
Benzo(g,h,i)perylene	0.12	J
Benzo(k)fluoranthene	0.085	J
Bis(2–ethylhexyl)phthalate	0.073	J
Chrysene	0.24	J
Fluoranthene	0.45	=
Indeno(1,2,3–cd)pyrene	0.091	J
Phenanthrene	0.34	J
Pyrene	0.42	J

Figure 4-2. Detected SVOCs in Surface Soil

background in 70 to 90% of the samples. Zinc was detected at nearly all sites at concentrations greater than background. Arsenic and beryllium were detected at all stations but only exceeded background concentrations in 10% of the samples. Cadmium, silver, and thallium were considered SRCs because no background data were available.

- Site RQL-026 in the northwest area of the quarry had the highest number of metals that exceeded background concentrations (16 SRCs) and generally had the highest concentrations. The sites with the lowest number of metals that exceeded background concentrations were RQL-025 (four) in the northern area of the site, RQL-032 (five) in the southern portion of the quarry bottom, and RQLsd-019 (five) located in the middle of the quarry bottom.
- There were 20 SVOCs detected and SVOCs were detected at all stations except RQLsd-013. Eight SVOCs were detected at nearly every sampling station: benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-*cd*)pyrene, phenanthrene, and pyrene. The MDCs for nearly all SVOCs were observed at RQL-026 in the northwest portion of the quarry bottom.

No VOCs, pesticides, or PCBs were detected in discrete surface soil samples, but three VOCs (2-butanone, acetone, and methylene chloride) were detected in dry sediment samples from the Groundwater Investigation (USACE 1999).

4.3 SURFACE SOIL MULTI-INCREMENT SAMPLES

For the purpose of multi-increment sampling, the bottom of Ramsdell Quarry, exclusive of the pond and landfill toe slope, was divided into approximately five equal areas (Figure 3-1). One multi-increment composite sample was collected from each of the five separate areas. Multi-increment samples were analyzed for explosives, TAL metals, cyanide, and SVOCs, and one multi-increment sample was also analyzed for propellants and pesticides/PCBs. Explosives, propellants, pesticides, PCBs, and VOCs were not detected in any of the multi-increment samples. The results for inorganics and SVOCs detected are discussed below for each of the five sampling areas. Analytical results are presented in Tables 4-6 and 4-7. Results from multi-increment samples were not aggregated and summary statistics were not calculated as was done for discrete samples. However, results were compared to facility-wide background values for evaluation purposes. Additionally, essential nutrients (calcium, iron, magnesium, potassium, and sodium) were not considered as site-related. Detected SVOCs were primarily PAH compounds and all are considered SRCs because background criteria were set to zero.

4.3.1 Multi-increment Area 1 (RQL-034)

Cyanide, cadmium, chromium, copper, lead, mercury, silver, and zinc were detected at concentrations that exceeded facility-wide background levels, which included the highest concentration of cyanide among the multi-increment samples (0.28 mg/kg). Fifteen SVOCs were also detected in this sample. Although concentrations were similar among sites, the maximum concentrations for nearly all SVOCs were detected in this sample.

4.3.2 Multi-increment Area 2 (RQL-035)

Antimony, barium, cadmium, chromium, cobalt, copper, cyanide, lead, mercury, nickel, silver, and zinc were detected at concentrations that exceeded facility-wide background levels. The highest concentrations

Table 4-6. Summary Data for Inorganics Detected in Surface Soil Multi-increment Samples

		Station				
Analyte (mg/kg)	**Site Background Criteria**	**RQL-034**	**RQL-035**	**RQL-036**	**RQL-037**	**RQL-038**
Cyanide	0	0.28 = *	0.24 = *	0.24 = *	0.18 J *	ND
Aluminum	1.77E+04	11,500 =	12,500 =	11,300 =	12,700 =	10,700 =
Antimony	9.60E-01	0.7 J	0.98 J *	1.8 J *	0.83 J	1.1 J *
Arsenic	1.54E+01	11.1 =	11.7 =	12.4 =	12.8 =	11.6 =
Barium	8.84E+01	81.1 =	107 = *	85.4 =	102 = *	66.8 =
Beryllium	8.80E-01	0.55 =	0.73 =	0.56 =	0.6 =	0.55 =
Cadmium	0	0.53 = *	3.7 = *	1.5 = *	0.61 = *	0.43 = *
Calcium	1.58E+04	2,250 =	6,130 =	1,950 =	5,350 =	1,700 =
Chromium	1.74E+01	17.5 = *	22.2 = *	22.5 = *	27.5 = *	17.5 = *
Cobalt	1.04E+01	8.6 =	10.8 = *	9.1 =	10.1 =	9.2 =
Copper	1.77E+01	54.3 = *	79.1 = *	71.9 = *	102 = *	37.9 = *
Iron	2.31E+04	19,600 =	24,500 = *	22,300 =	32,000 = *	22,900 =
Lead	2.61E+01	49.1 = *	108 = *	87.3 = *	73.5 = *	38.1 = *
Magnesium	3.03E+03	1,960 =	2,950 =	2,850 =	6,120 = *	2,490 =
Manganese	1.45E+03	571 =	733 =	526 =	682 =	515 =
Mercury	3.60E-02	0.11 = *	0.06 J *	0.53 = *	0.043 J *	0.61 = *
Nickel	2.11E+01	15.5 =	22.8 = *	27.8 = *	27.9 = *	20.9 =
Potassium	9.27E+02	1,210 J *	1,230 J *	1,090 J *	1,390 J *	1,320 J *
Selenium	0	0.61 J	0.85 J	0.76 J	0.64 J	0.57 J
Silver	0	0.19 = *	1 = *	0.28 = *	0.39 = *	0.11 J *
Sodium	1.23E+02	31.5 =	68.8 =	41.7 =	88.8 =	35.7 =
Vanadium	3.11E+01	20.5 =	22.3 =	22.8 =	22.4 =	18.6 =
Zinc	6.18E+01	134 = *	277 = *	271 = *	206 = *	123 = *

ND = Non-detect result.
= – Analyte present and concentration accurate.
* – Value above facility-wide background criterion.
J – Estimated value less than reporting limits.

Table 4-7. Summary Data for SVOCs Detected in Surface Soil Multi-increment Samples

	Station				
Analyte (mg/kg)	**RQL-034**	**RQL-035**	**RQL-036**	**RQL-037**	**RQL-038**
Acenaphthene	1.3 J	ND	1.1 J	ND	ND
Anthracene	3.4 J	1.6 J	3.1 J	0.98 J	ND
Benz(*a*)anthracene	5 J	2.1 J	3.7 J	2 J	ND
Benzo(*a*)pyrene	3.8 J	1.7 J	2.8 J	1.6 J	ND
Benzo(*b*)fluoranthene	3.1 J	1.4 J	2.6 J	1.4 J	ND
Benzo(*g,h,i*)perylene	2 J	1.1 J	1.6 J	0.98 J	ND
Benzo(*k*)fluoranthene	2.9 J	1.5 J	2.4 J	1.3 J	ND
Carbazole	1.3 J	0.8 J	1.4 J	ND	ND
Chrysene	4.3 J	2 J	3.4 J	1.8 J	ND
Dibenzofuran	0.74 J	ND	0.66 J	ND	ND
Fluoranthene	10 J	5.3 J	8.3 J	4.1 J	ND
Fluorene	1.4 J	0.63 J	1.1 J	ND	ND
Indeno(1,2,3-*cd*)pyrene	2 J	1.1 J	0.87 J	0.95 J	ND
Phenanthrene	12 J	5.5 J	9.6 J	2.9 J	ND
Pyrene	10 J	4.6 J	8.6 J	4.4 J	ND

ND = Non-detect result.
SVOC = Semivolatile organic compound.
J – Estimated value less than reporting limits.

of barium (107 mg/kg), cadmium (3.7 mg/kg), cobalt (10.8 mg/kg), lead (108 mg/kg), silver (1 mg/kg), and zinc (277 mg/kg) among the five multi-increment sampling areas were detected in this sample. Thirteen SVOCs were also detected in this sample.

4.3.3 Multi-Increment Area 3 (RQL-036)

Antimony, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc were detected at concentrations that exceeded background levels. The highest concentration of antimony was found at this site (1.8 mg/kg). Fifteen SVOCs were also detected.

4.3.4 Multi-Increment Area 4 (RQL-037)

Cyanide, barium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc were detected at concentrations that exceeded background levels. The highest concentrations of chromium (27.5 mg/kg), copper (102 mg/kg), and nickel (27.9 mg/kg) among the five multi-increment samples were detected in this area. Eleven SVOCs were also detected in this sample.

4.3.5 Multi-Increment Area 5 (RQL-038)

Antimony, cadmium, chromium, copper, lead, mercury, silver, and zinc were detected at concentrations that exceeded background levels, which included the highest concentration of mercury (0.61 mg/kg) among the five multi-increment sampling areas. SVOCs were not detected in this sample.

4.3.6 Summary of Surface Soil Multi-Increment Samples

Multi-increment sample results represent average concentrations within their respective sampling areas. Therefore, the results are not directly comparable to the results of discrete samples collected within the same areas. It is noted that discrete sample results from stations RQL-026 and -027 within multi-increment sample Area 2 indicated the presence of explosives compounds; however, the multi-increment sample collected from sample Area 2 did not contain detectable explosives. Likewise, discrete samples collected in Area 1 (RQL-025) and Area 4 (RQL-030) contained detectable explosives or propellants, which were not detected in the corresponding multi-increment samples. This pattern suggests that the occurrence of explosives in the bottom of Ramsdell Quarry is extremely sporadic. Despite collection of 30 random aliquots for each multi-increment sample area, the likelihood of capturing detectable levels of explosives was low.

This conclusion is specific only to the occurrence of explosives in the bottom of Ramsdell Quarry. It is noted that six of ten biased soil samples in the quarry did not contain detectable explosives. Two samples contained concentrations < 1 ppm; only two of ten samples had concentrations > 1 ppm. Thus, the biased samples also support the conclusion that contamination is sporadic. Note that the multi-increment sampling method provides a different result than biased sampling methods by design. Multi-increment samples provide an average concentration across each exposure area; thus, direct comparison of multi-increment results to biased samples, which target maximum concentrations within an exposure area, it not feasible.

4.4 GROUNDWATER

The previous Groundwater Investigation at Ramsdell Quarry (USACE 1999; 2000) was designed to evaluate the shallow groundwater hydrogeologic conditions, including groundwater flow direction, seasonal changes, and the hydraulic and geochemical relationships between the surface water in the pond and the groundwater. These characteristics helped determine whether the closed landfill was in compliance with Ohio solid waste regulations post-closure requirements. Results of the Groundwater

Investigation indicated the presence of low levels of explosives in the furthest downgradient well installed at the time. In addition, explosives were detected in a well (RQLmw-006) that was hydraulically upgradient of the landfill during most of the year, except during maximum high water level conditions in the quarry pond.

Accordingly, the Phase I RI included installation and sampling of four wells (RQLmw-012, -013, -014, and -015) to define the maximum downgradient (north-northwest) extent of contaminants associated with Ramsdell Quarry. Two additional wells (RQLmw-016 and -017) were also installed to evaluate whether contaminants previously observed in upgradient well RQLmw-06 potentially originated from Load Line 1 (see Chapter 3.0).

The monitoring wells were sampled for dissolved (filtered) metals, cyanide, VOCs, SVOCs, pesticides, and PCBs. In addition, field measurements of pH, temperature, specific conductance, and dissolved oxygen were recorded for each sample. Analytical data for the groundwater sampling effort are presented in Appendix G. Because all of the Phase I RI wells at RQL are bedrock wells, the bedrock-filtered groundwater background criteria were employed for the screening to identify SRCs. Data summary statistics and screening results to identify SRCs are presented in Table 4-8.

4.4.1 Explosives and Propellants

No explosives or propellants were present at concentrations above detection limits in groundwater samples collected during the Phase I RI.

4.4.2 Inorganics

Table 4-8 contains summary statistics and results of the background comparison for metals and cyanide in groundwater samples. The results are presented in Table 4-9 on a well-by-well basis. Inorganics were detected in all wells, 12 of which were identified as SRCs and further evaluated for occurrence and distribution. Aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, and vanadium were identified as SRCs by virtue of the fact that these analytes were not detected in the background data set; thus, the background criteria were set to zero. Six constituents were eliminated as potential groundwater SRCs because they were either considered essential nutrients (calcium, iron, magnesium, potassium, and sodium) or the concentration was less than background (barium). It is noted that iron concentrations routinely exceeded the Ohio secondary MCL of 0.3 mg/L. However, the facility-wide background value for iron is also greater than the secondary MCL.

Well RQLmw-013 had the highest number of inorganic SRCs (eight), followed by RQLmw-012 (six). Generally, higher concentrations of many inorganic SRCs were observed in these two wells. Detectable levels of cadmium and lead were restricted to only these two wells. The sites with the fewest identified inorganic SRCs were RQLmw-014 and -015 (three SRCs each).

Manganese, nickel, and zinc were detected at all sites and exceeded their background values in 30 to 50% of the samples. The maximum concentrations were found at RQLmw-016 (manganese at 6.17 mg/L) and RQLmw-017 (nickel at 0.306 mg/L and zinc at 0.312 mg/L). These sites are located in the south and southwestern areas of the AOC. Cobalt was also detected at all sites, with the highest concentration of cobalt found at RQLmw-017 (0.07 mg/L). Arsenic was frequently detected (four of six samples); however, its distribution included similar concentrations in both upgradient and downgradient wells.

Antimony, cadmium, lead, and vanadium were infrequently detected; these constituents were only detected at one or two wells. Cyanide was not detected in any groundwater samples collected during the Phase I RI.

Table 4-8. Summary Statistics and Determination of SRCs in Groundwater Samples

Analyte	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL_{95} of Mean	Exposure Concentration	MCL	Site Background Criteria	Max Detect > Background	Site Related?
Inorganics (mg/L)										
Aluminum	3/6	1.27E+00	7.88E-02	6.13E+00	6.98E+06	6.13E+00		0	Yes	Yes
Antimony	1/6	2.34E-04	5.80E-04	5.80E-04	3.74E-04	3.74E-04	6.00E-03	0	Yes	Yes
Arsenic	4/6	2.13E-03	9.50E-04	6.80E-03	7.64E-02	6.80E-03	1.00E-02	0	Yes	Yes
Barium	6/6	2.17E-02	4.20E-03	4.54E-02	3.32E-02	3.32E-02	2.00E+00	2.56E-01	No	No
Beryllium	4/6	1.49E-04	7.60E-05	5.70E-04	2.31E-02	5.70E-04	4.00E-03	0	Yes	Yes
Cadmium	2/6	2.37E-04	4.80E-04	7.00E-04	4.69E-04	4.69E-04	5.00E-03	0	Yes	Yes
Calcium[b]	6/6	1.11E+02	1.98E+01	4.52E+02	1.45E+03	4.52E+02		5.31E+01	No	No
Cobalt	6/6	2.65E-02	6.70E-03	7.00E-02	1.58E-01	7.00E-02		0	Yes	Yes
Copper	3/6	1.55E-03	2.00E-03	3.40E-03	2.55E-03	2.55E-03	1.30E+00[c]	0	Yes	Yes
Iron[b]	4/6	2.56E+00	8.20E-03	7.25E+00	5.07E+00	5.07E+00		1.43E+00	Yes	No
Lead	2/6	3.92E-04	5.10E-04	1.30E-03	7.80E-04	7.80E-04	1.50E-02[c]	0	Yes	Yes
Magnesium[b]	6/6	2.26E+01	8.97E+00	5.73E+01	5.89E+01	5.73E+01		1.50E+01	Yes	No
Manganese	6/6	2.32E+00	2.66E-01	6.17E+00	4.42E+01	6.17E+00		1.34E+00	Yes	Yes
Nickel	6/6	8.98E-02	1.64E-02	3.06E-01	1.04E+00	3.06E-01		8.34E-02	Yes	Yes
Potassium[b]	6/6	3.27E+00	1.77E+00	5.02E+00	4.88E+00	4.88E+00		5.77E+00	No	No
Sodium[b]	6/6	7.34E+00	1.50E+00	2.32E+01	4.03E+01	2.32E+01		5.14E+01	No	No
Vanadium	1/6	7.67E-04	1.60E-03	1.60E-03	1.10E-03	1.10E-03		0	Yes	Yes
Zinc	6/6	1.03E-01	8.20E-03	3.12E-01	2.10E+01	3.12E-01		5.23E-02	Yes	Yes
Volatile Organic Compounds (mg/L)										
Carbon Disulfide	6/6	2.67E-03	6.60E-04	7.90E-03	1.82E-02	7.90E-03		0	Yes	Yes

[a] Values less than detection were set to one-half of the reporting limit in calculation of the average.
[b] Eliminated as an SRC based on the essential element screen.
[c] Drinking water action levels.
SRC = Site-related contaminant.
UCL_{95} = 95% upper confidence limit.

Table 4-9. Summary Data for Inorganics and VOCs Detected in Groundwater

Analyte	Station					
	RQLmw-012	**RQLmw-013**	**RQLmw-014**	**RQLmw-015**	**RQLmw-016**	**RQLmw-017**
Inorganics (mg/L)						
Aluminum	1.38 = *	6.13 = *				0.0788 = *
Antimony				0.00058 J *		
Arsenic		0.002 = *		0.0068 = *	0.0025 = *	0.00095 J *
Barium	0.0238 J	0.0454 J	0.0138 J	0.0042 =	0.0261 =	0.0167 J
Beryllium	0.000076 J *	0.00057 = *			0.000076 J *	0.00015 = *
Cadmium	0.0007 = *	0.00048 = *				
Calcium	50.6 =	19.8 =	40.2 =	20.4 =	452 = *	81.3 = *
Cobalt	0.0084 = *	0.0452 = *	0.0067 = *	0.0141 = *	0.0143 = *	0.07 = *
Copper	0.0034 J *	0.002 J *				0.0022 J *
Iron	0.0082 J	4.6 = *	3.47 = *		7.25 = *	
Lead	0.0013 = *	0.00051 J *				
Magnesium	13.6 =	11.9 =	17.3 = *	8.97 =	57.3 = *	26.3 = *
Manganese	0.266 =	0.584 =	1.59 = *	0.682 =	6.17 = *	4.63 = *
Nickel	0.0202 =	0.0906 = *	0.0164 =	0.0437 =	0.062 =	0.306 = *
Potassium	5.02 =	2.87 =	4.04 =	1.77 =	2.67 =	3.24 =
Sodium	3.63 =	23.2 =	3.79 =	1.5 =	6.82 =	5.12 =
Vanadium			0.0016 J *			
Zinc	0.0415 =	0.235 = *	0.0111 =	0.0082 J	0.0097 J	0.312 = *
Volatile Organic Compounds (mg/L)						
Carbon Disulfide	0.00066 J	0.0025 =	0.00069 J	0.0033 =	0.0079 =	0.00095 J

VOC = Volatile organic compound.
= = Analyte present and concentration accurate.
* = Value above facility-wide background criterion.
J = Estimated value less than reporting limits.
Blank cells represent non-detect values.

4.4.3 Volatile Organic Compounds

Carbon disulfide was the only VOC detected in Phase I RI groundwater samples (Tables 4-8 and 4-9). Because this compound was not detected in background samples, it is considered a SRC. The highest concentrations were found at RQLmw-016, located upgradient of the AOC. Although the data verification process did not indicate that the results should be qualified, the occurrence of low levels of carbon disulfide at similar concentrations in all of the Phase I RI wells suggests that it is an analytical artifact. During the previous Groundwater Investigation, trace levels of carbon disulfide were detected once in two separate wells (RQLmw-06 in July 1998 and RQLmw-08 in April 1999). Thus, previous data from monitoring wells closer to the former landfill do not indicate a widespread distribution of this VOC.

4.4.4 Semivolatile Organic Conpounds, Pesticides, and PCBs

No SVOCs, pesticides, or PCBs were present at concentrations above detection limits in groundwater samples collected during the Phase I RI.

4.4.5 Summary of Groundwater

The lack of explosives in Phase I RI groundwater monitoring wells indicates that the extent of explosives contamination related to Ramsdell Quarry is limited to the immediate vicinity of the AOC and has been defined by the monitoring network. Additionally, the lack of explosives in upgradient wells RQLmw-017 and -016 indicate that Load Line 1 is not the source for explosives previously observed in well RQLmw-006 during the Groundwater Investigation. Inorganics were detected in all groundwater wells. Twelve inorganics were identified as SRCs, many by virtue of the fact that they were not detected in the background sample population (aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, and vanadium). Manganese, nickel, and zinc were detected at all sites and exceeded their background values in 30 to 50% of the samples. The occurrence and distribution of inorganic SRCs do not indicate migration of contaminants beyond the monitoring network boundary established in the Phase I RI. Detectable levels of cadmium and lead in wells RQLmw-012 and -013 may reflect contaminant flux from Ramsdell Quarry; however, concentrations are extremely low. Persistent trace levels of carbon disulfide observed in Phase I RI monitoring wells do not appear to be related to former AOC operations.

4.5 MUNITIONS AND EXPLOSIVES OF CONCERN AVOIDANCE SURVEY SUMMARY

Because of the operational history of Ramsdell Quarry, all sampling activities were overseen by a certified MEC specialist (see Appendix L). MEC was not found during the Phase I RI. However, various metallic scrap was observed, including some potential MEC scrap, on the eastern slope of the quarry and in the wooded area south of RQL in the vicinity of RQLmw-017.

4.6 SUMMARY OF CONTAMINANT NATURE AND EXTENT

Based on the evaluation of the occurrence and distribution of contamination in surface soil and groundwater, the following conclusions are made.

Surface Soil Discrete Samples

- Explosives and propellants were detected at four discrete surface soil sample sites, RQL-025, -026, -027 and -030. The highest levels of explosives generally were observed in the western and northwestern portion of the quarry bottom along the toe slope of the landfill.

- Fourteen inorganic analytes were identified as SRCs, including antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, thallium, and zinc. Site RQL-026 in the northwest area of the quarry had the highest number of metals that exceeded background concentrations (16). The sites with the lowest number of metals that exceeded background concentrations were RQL-025 (four) in the northern area of the site and RQL-032 (five) in the southern area of the site.

- There were 20 SVOCs detected and SVOCs were detected at all sites. The MDCs for nearly all SVOCs were observed at RQL-026 in the northwest portion of the quarry bottom.

- VOCs, pesticides, and PCBs were not detected.

Surface Soil Multi-increment Samples

- Inorganic constituents were detected at all sites. The number of constituents that exceeded background concentrations ranged from 8 to 12, with antimony, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc all frequently observed above background criteria.

- SVOCs were detected at all sites except RQL-038. The number of SVOCs detected ranged from 11 to 15. All SVOCs are considered SRCs because no background data were available. The maximum concentrations for nearly all analytes were observed at RQL-034.

- Explosives, propellants, pesticides, PCBs, and VOCs were not detected in multi-increment samples.

Groundwater

- Explosives, propellants, SVOCs, pesticides, and PCBs were not detected.

- The lack of explosives contaminants in Phase I RI monitoring wells indicates that the monitoring network defines the extent of migration from the AOC. Also, the absence of explosives in wells RQLmw-016 and -017 indicate that Load Line 1 was not a source of explosives observed during the Groundwater Investigation in well RQLmw-006.

- Twelve metals were identified as SRCs, including aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc. Site RQLmw-013 had the highest number of analytes detected (16) followed by RQLmw-012 (15). The sites with the fewest analytes detected were RQLmw-014 and -015 (11).

Carbon disulfide was detected in all six Phase I RI wells. Previous sampling from wells located closer to the landfill and the distribution characteristics of this VOC in both upgradient and downgradient wells do not indicate that Ramsdell Quarry is a source, rather the presence may potentially be an analytical artifact.

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5.0 CONTAMINANT FATE AND TRANSPORT

5.1 INTRODUCTION

This chapter describes the potential migration pathways and mechanisms for transport of chemical substances found in surface and subsurface soils and groundwater at RQL. Computer-based contaminant fate and transport analyses were performed to predict the rate of contaminant migration in the identified primary transport media and to project likely future contaminant concentrations at receptor locations through these media. The ultimate objectives of these analyses are to evaluate potential future impacts to human health and the environment and to provide a basis for evaluating the effectiveness of the future remedial alternatives.

Fate and transport modeling was used to simulate vertical transport of contaminants from a principal source area containing maximum observed contaminants in soil to groundwater, as well as horizontal transport within the groundwater system from the source area to receptor locations. A summary of the principles of contaminant fate and transport is presented in this chapter along with the results of modeling activities. Section 5.2 describes the physical and chemical properties of the SRCs (including metals, organic compounds, and explosives found at RQL). Section 5.3 presents a conceptual model for contaminant fate and transport at RQL that considers site topography, hydrogeology, contaminant sources, and release mechanisms through the transport media. Section 5.4 presents a soil leachability analysis to identify contaminant migration contaminants of potential concern (CMCOPCs). Section 5.5 describes the fate and transport modeling. The summary and conclusions of the fate and transport analyses are presented in Section 5.6.

5.2 PHYSICAL AND CHEMICAL PROPERTIES OF SITE-RELATED CONTAMINANTS

Inorganic and organic constituents in soil and groundwater are in continuous chemical and physical interaction with ambient surface and subsurface environments. The observed distributions of chemical concentrations in the environment are the result of these interactions. These interactions also determine the chemical fate of these materials in the transport media. Chemicals released into the environment are susceptible to several degradation pathways including hydrolysis, oxidation, reduction, isomerization, photolysis, photo-oxidation, biotransformation, and biodegradation. Transformation products resulting from these processes will behave distinctively in the environment.

The migration of chemical constituents through the transport media is governed by the physical and chemical properties of the constituents and the surface and subsurface media through which the chemicals are transferred. In a general way, chemical constituents and structures with similar physical and chemical characteristics will show similar patterns of transformation, transport, or attenuation in the environment. Solubility, vapor pressure data, chemical partitioning coefficients, degradation rates, and Henry’s Law Constant provide information that can be used to evaluate contaminant mobility in the environment. Partitioning coefficients are used to assess the relative affinities of compounds for solution or solid phase adsorption. However, the synergistic effects of multiple migrating compounds and the complexity of soil/water interactions, including pH and oxidation-reduction potential (Eh), grain size, and clay mineral variability, are typically unknown.

The physical properties of the chemical constituents that were detected in soil media at RQL are summarized in Tables H-1, H-2, and H-3 of Appendix H. The properties are used to assess the anticipated behavior of each compound under environmental conditions.

5.2.1 Chemical Factors Affecting Fate and Transport

The water solubility of a compound is a measure of the saturated concentration of the compound in water at a given temperature and pressure. The tendency for a compound to be transported by groundwater is directly related to its solubility and inversely related to both its tendencies to adsorb to soil and to volatilize from water (OGE 1988). Compounds with high water solubilities tend to desorb from soils, are less likely to volatilize from water, and are susceptible to biodegradation. The water solubility of a compound varies with temperature, pH, and the presence of other dissolved constituents (including organic carbon and humic acids).

The octanol-water partition coefficient (Kow) can be used to estimate the tendency for a chemical to partition between environmental phases of different polarity. The Kow is a laboratory-determined ratio of the concentration of a chemical in the n-octanol phase of a two-phase system to the concentration in the water phase. Compounds with log Kow values less than 1 are highly hydrophilic, while compounds with log Kow values greater than 4 will partition to soil particles (Lyman, Reehl, and Rosenblatt 1990).

The water/organic carbon partition coefficient (Koc) is a measure of the tendency of a compound to partition between soil and water. The Koc is defined as the ratio of the absorbed compound per unit weight of organic carbon to the aqueous solute concentration. This coefficient can be used to estimate the degree to which a compound will adsorb to soil and, thus, not migrate with groundwater. The higher the Koc value, the greater is the tendency of the compound to partition into soil (OGE 1988). The sorption coefficient (Kd) is calculated by multiplying the Koc value by the fraction of organic carbon in the soil.

Vapor pressure is a measure of the pressure at which a compound and its vapor are in equilibrium. The value can be used to determine the extent to which a compound would travel in air, as well as the rate of volatilization from soils and solution (OGE 1988). In general, compounds with vapor pressures lower than 10-7 mm mercury will not be present in the atmosphere or air spaces in soil in significant amounts, while compounds with vapor pressures higher than 10^{-2} mm mercury will exist primarily in the air (Dragun 1988).

The Henry's Law Constant value (KH) for a compound is a measure of the ratio of the compound’s vapor pressure to its aqueous solubility. The KH value can be used to make general predictions about the compound’s tendency to volatilize from water. Substances with KH values less than 10^{-7} atm-m^3/mol will generally volatilize slowly, while compounds with a KH greater than 10^{-3} atm-m^3/mol will volatilize rapidly (Lyman, Reehl, and Rosenblatt 1990).

5.2.2 Biodegradation

Organic chemicals with differing chemical structures will biodegrade at different rates. Primary biodegradation consists of any biologically induced structural change in an organic chemical, while complete biodegradation is the biologically mediated degradation of an organic compound into carbon dioxide, water, oxygen, and other metabolic inorganic products (Dragun 1988). The first order biodegradation rate of an organic chemical is proportional to the concentration:

$$-dC/dt = kC \,, \qquad \textbf{(5-1)}$$

where

C = concentration,
t = time,
k = biodegradation rate constant = $\ln 2 / t_{1/2}$,
$t_{1/2}$ = biodegradation half-life.

The biodegradation half-life is the time necessary for half of the chemical to react. The biodegradation rate of an organic chemical is generally dependent on the presence and population size of soil microorganisms that are capable of degrading the chemical.

5.2.3 Inorganic Compounds

Inorganic constituents detected in soil samples at RQL are associated with both the aqueous phase and with leachable metal ions on soil particles. The transport of these materials from unsaturated soils to the underlying groundwater is controlled by the physical processes of precipitation, infiltration, chemical interaction with the soil, and downward transport of removed metal ions by continued infiltration. The chemistry of inorganic interaction with percolating precipitation and varying soil conditions is complex and includes numerous chemical transformations that may result in altered oxidation states, ion exchange, adsorption, precipitation, or complexation. The chemical reactions, which are affected by environmental conditions including pH, oxidation/reduction conditions, and the type and amount of organic matter, clay, and the presence of hydrous oxides, may act to enhance or reduce the mobility and toxicity of the metal ions. In general, these reactions are reversible and add to the variability commonly observed in distributions of inorganics in soil.

The chemical form of an inorganic constituent determines its solubility and mobility in the environment; however, chemical speciation is complex and difficult to delineate in routine laboratory analysis. Metals in soil are commonly found in several forms, including dissolved concentrations in soil pore water; metal ions occupying exchange sites on inorganic soil constituents, specifically adsorbed metal ions on inorganic soil constituents; metal ions associated with insoluble organic matter; precipitated inorganic compounds as pure or mixed solids; and metal ions present in the structure of primary or secondary minerals.

The dissolved (aqueous) fraction and its equilibrium fraction are of primary importance when considering the migration potential of metals associated with soil. Of the inorganic compounds that are likely to form, chlorides, nitrates, and nitrites are commonly the most soluble. Sulfate, carbonate, and hydroxides generally have low to moderate solubility. Soluble compounds are transported in aqueous form subject to attenuation, whereas less soluble compounds remain as a precipitate and limit the overall dissolution of the metal ions. The solubility of the metal ions also is regulated by ambient chemical conditions, including pH and oxidation/reduction.

The attenuation of metal ions in the environment can be estimated numerically using the retardation factor (R_d). The extent to which the velocity of the contaminant is slowed is largely derived from the soil/water partitioning coefficient (K_d). The retardation factor is calculated using the following equation:

$$R_d = 1 + (K_d \rho_b)/\phi_w , \qquad \textbf{(5-2)}$$

where

ρ_b = the soil bulk dry density, (g/cm^3),
ϕ_w = soil moisture content, (dimensionless).

Metal ion concentrations in the environment do not attenuate by natural or biological degradation because of low volatility and solubility of the ions. Metals concentrations may be biotransformed or bioconcentrated through microbial activity.

5.2.4 Organic Compounds

Organic compounds, such as SVOCs or VOCs, detected in soil, sediment, or water at RQL may be transformed or degraded in the environment by various processes, including hydrolysis, oxidation/reduction, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic compounds in the transport media can vary from minutes to years, depending on environmental conditions and the chemical structures of the compounds. Some types of organic compounds are very stable, and degradation rates can be very slow. Organic degradation may either enhance (through the production of more toxic byproducts) or reduce (through concentration reduction) the toxicity of a chemical in the environment.

5.2.5 Explosives-Related Compounds

Explosive compounds were detected in soil at RQL. With regard to these compounds, microbiological and photochemical transformation may affect the fate and distribution of this class of constituents in the environment as well. For example, based on the results of culture studies involving the removal of TNT by activated sludge microorganisms, it has been concluded that TNT undergoes biotransformation, but not biodegradation (Burrows et al. 1989). It has been found (Funk et al. 1993) that the anaerobic metabolism occurs in two stages. The first stage is the reductive stage in which TNT is reduced to its amino derivatives. In the second stage, degradation to non-aromatic products begins after the reduction of the third nitro group.

The biotransformation pathway for TNT in simulated composting systems is shown on Figure 5-1 (Kaplan and Kaplan 1990). The biotransformation of 2,4-DNT has been systematically studied in laboratory cell cultures. The pathway proposal for this biotransformation is shown in Figure 5-2. The reduction products include the amino and azoxy derivatives as observed with TNT biotransformation. As with TNT and DNT, the principal mode of microbial transformation of the nitroaromatic compounds trinitrobenzene and 1,3-DNB is reduction of nitro groups to form amino groups.

Limited information exists regarding biotransformation or biodegradation of RDX. Studies indicate biodegradation of RDX occurs most rapidly in anaerobic environments in the presence of other nutrients. Aerobic degradation has also been observed in bench-scale tests in the presence of a TOC source (stream sediment), although rates were slower. Photolytic degradation of RDX is reported as a major transformation process (Card and Autenrieth 1998). End products of the anaerobic pathway include formaldehyde and nitramine (Roberts and Kotharu 2004). The end products of the photolytic pathway include nitrate, nitrite, and formaldehyde (Card and Autenrieth 1998). One pilot study being conducted by USACE (USACE 2004a) that evaluates treatment of pink water wastes using an anaerobic fluidized-bed granular activated carbon bioreactor indicated RDX biodegradation in the presence of ethanol. Such data may be useful for evaluating the potential use of enhanced bioremediation as a remedial option.

5.3 CONCEPTUAL MODEL FOR FATE AND TRANSPORT

To effectively represent site-specific conditions in numerical modeling applications, the CSM is relied upon to provide inputs on site conditions that serve as the framework for quantitative modeling. Environmental site conditions described by the CSM, which is outlined in Chapter 2.0 and refined in Chapter 8.0, include contaminant source information, the surrounding geologic and hydrologic conditions, and the magnitude of SRCs and their current spatial distribution. This information is used to identify chemical migration pathways at RQL for fate and transport analysis. The predictive function of the CSM, which is of primary importance to contaminant fate and transport analysis, relies on known information and informed

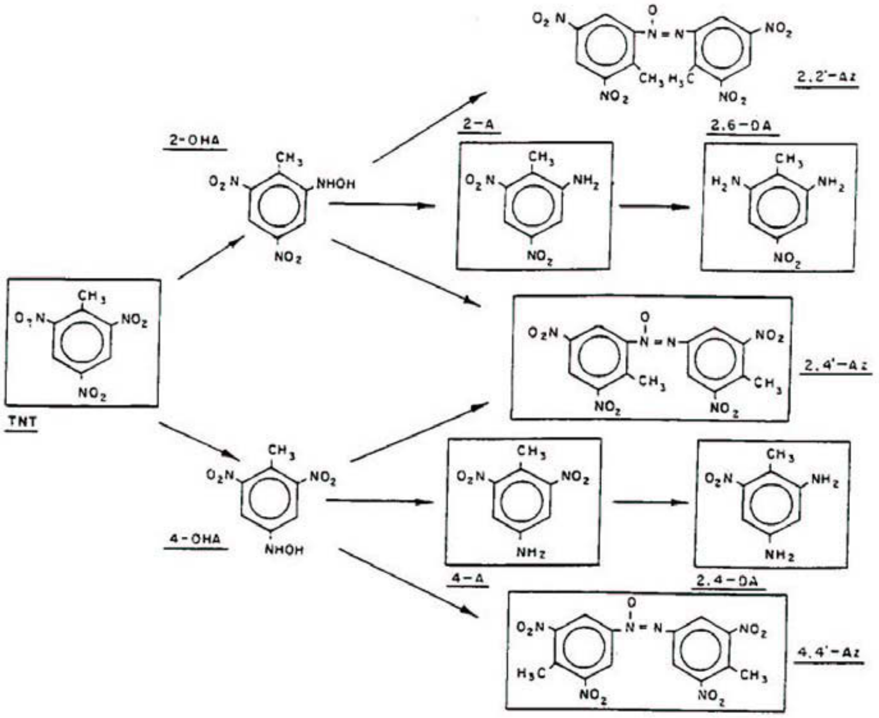


Figure 5-1. 2,4,6-TNT Biotransformation Pathway

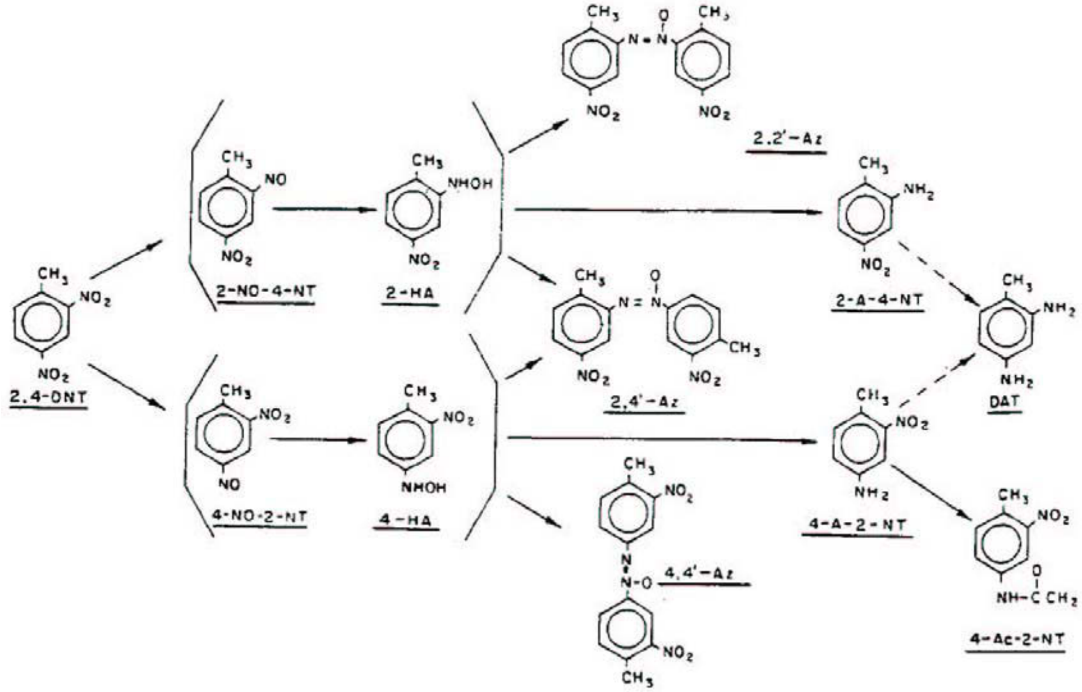


Figure 5-2. 2,4-DNT Biotransformation Pathway

assumptions about the site. Assumptions contained in the CSM are reiterated throughout this section. The better the information and the greater the accuracy of the assumptions, the more accurately the CSM describes the AOC and, therefore, the more reliable the numerical modeling predictions can be.

A summary of the salient elements of the CSM that apply to fate and transport modeling follows.

5.3.1 Contaminant Sources

Based on the analysis of the field data, the following contaminant sources have been identified.

- Metals and explosive residues are present primarily in the surface soil below the footprint of RQL. Note that RQL includes two soil sources: the quarry bottom and the landfill. Soil samples were collected from below the quarry; no such sample was collected below the landfill. Therefore, the source was delineated below the quarry only. Numerous inorganic SRCs (see Table 4-2) were identified in these areas: antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, thallium, and zinc. Organic SRCs identified were primarily PAHs (see Table 4-2). Explosive SRCs identified were: 1,3-DNB; 2,4,6-TNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; HMX; nitroglycerin; and RDX.

- Inorganics are present in the groundwater outside of the immediate vicinity of Ramsdell Quarry. Note that the quarry and the landfill act as the primary sources, while Load Line 1 may act as a secondary source. Inorganic SRCs identified in groundwater are aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc (see Table 4-8). Carbon disulfide was detected at levels less than reporting limits and was considered an SRC because its background criterion is zero.

The source area for leachate modeling was selected considering surface and subsurface soil samples in RQL. An area 435 × 370 ft, containing RQLsd-015, RQL-037, RQL-033, RQL-034, and others was considered. This source area is shown schematically on the CSM figure in Chapter 8.0.

5.3.2 Hydrogeology

A complete description of the site geology and hydrology is provided in Chapter 2.0 and is summarized below.

- Ground elevations across RQL vary from approximately 291 to 302 m (955 to 990 ft) amsl. In general, the land surface slopes towards a pond in the quarry.

- Only a thin soil cover exists at the AOC with underlying sandstone deposits.

- Groundwater flow is consistent with regional surface drainage patterns, with overall flow towards Sand Creek to the northeast. The elevation of the groundwater table varies from 950 to 955 ft amsl.

- Contaminant concentrations are highest within the 0 to 1-ft surface soil interval in the western portion of the quarry floor. Contaminant leaching pathways from soil to the water table are through the thin soil cover and a fractured sandstone interval. A sediment layer (up to 4 ft thick) is present in the bottom of the pond. The layer may reduce hydraulic communication somewhat between the pond and the underlying sandstone.

5.3.3 Contaminant Release Mechanisms and Migration Pathways

Based on the information presented above, the following contaminant release mechanisms and migration pathways have been identified.

Water infiltrating through contaminated surface soils may leach contaminants into the groundwater. The factors that affect the leaching rate include a contaminant's solubility, K_d, and the amount of infiltration. Insoluble compounds will precipitate out of solution in the subsurface or remain in their insoluble forms with little leaching. For the contaminants detected at RQL, sorption processes and the K_d generally will have the greatest effect on leaching. Another factor that affects whether a contaminant will reach the water table through infiltration of rainwater is the contaminant's rate of decay. Most of the organic and explosives compounds decay at characteristic rates that are described by the substance's half-life. For a given percolation rate, those contaminants with long half-lives have a greater potential for contaminating groundwater than those with shorter half-lives.

Release by gaseous emissions and airborne particulates is not significant at RQL. VOCs were not detected in surface soil and were detected at low, estimated concentrations in sediment during previous investigations. Therefore, there is likely little to no gaseous emission, and contaminant levels in the air pathway are minor to nonexistent.

5.3.4 Water Balance

The potential for contaminant transport begins with precipitation. Infiltration is the driving mechanism for leaching of soil contaminants to groundwater. The actual amount of rainwater available for flow and infiltration to groundwater is highly variable and dependent upon soil type and climatic conditions. A water balance calculation can be used as a tool to quantitatively account for all the components of the hydrologic cycle at RQL. The quantified elements of the water balance are used for inputs to the soil leaching and groundwater transport models discussed later. The components of a simple steady-state water balance model include precipitation (P), evapotranspiration (ET), surface runoff (Sr), and groundwater recharge or percolation (Gr). These terms are defined as follows:

$$P = ET + Sr + Gr, \qquad \textbf{(5-3)}$$

or

$$\text{Rainwater available for flow} = Sr + Gr = P - ET. \qquad \textbf{(5-4)}$$

A relatively moderate amount of runoff occurs from the site. It is expected that loss of runoff occurs in the form of evaporation. The remaining water after runoff is infiltration, which includes loss to the atmosphere by evapotranspiration. The water balance estimations were developed using the Hydrologic Evaluation of Landfill Performance model (Schroeder et al. 1994) calculations for RQL site conditions using precipitation and temperature data for the 100-year period generated synthetically using coefficients for Cleveland, Ohio.

The annual average water balance estimates for RQL indicate an evapotranspiration of 28% [0.26 m (10.3 in.)] of total precipitation [0.94 m (37 in.)]. The remaining 72% [0.68 m (27 in.)] of rainwater is available for surface water runoff and infiltration to groundwater. Of the 0.68 m (27 in.) of rainwater available for runoff or infiltration, groundwater recharge (infiltration) accounts for 10% [0.095 m (3.7 in.)], and surface runoff accounts for the remaining 62% [0.60 m (23. in.)].

5.3.5 Natural Attenuation of Contaminants in the Ramsdell Quarry Landfill

Natural attenuation accounting for advection, dispersion, sorption, volatilization, and decay effects can effectively reduce contaminant toxicity, mobility, or volume (mass) to levels that are protective of human health and the ecosystem within an acceptable, site-specific time period. Therefore, natural attenuation as a remedial alternative has become a cost-effective approach to site remediation. The overburden materials at RQL generally have sufficient organic carbon content to cause retardation of organic constituents; however, the very thin overburden thickness probably negates much of this effect. In addition, the clay mineralogy results in significant cation retardation of inorganic constituents by adsorption reactions. Attenuation through adsorption occurs in the vadose zone because of higher organic carbon and clay content in the overburden materials. However, the available data collected to date do not allow quantification of natural attenuation. A focused investigation would be required to quantify natural attenuation at this site and to determine if it would be a viable potential remedial approach.

5.4 SOIL LEACHABILITY ANALYSIS

Soil leachability analysis is a screening analysis performed to define CMCOPCs. The CMCOPCs are defined as the constituents that may pose the greatest problem if they are migrating from a specified source.

5.4.1 Soil Screening Analysis

The first step of the soil screening analysis is the development of SRCs, as discussed in Chapter 4.0. The chemical data in soils were grouped into one area aggregate (Figure 4-1) and screened using frequency of detection and RVAAP facility-wide background criteria to identify SRCs. The aggregate included all Phase I RI soil samples and three sediment samples collected during the previous Groundwater Investigation, which were considered as dry sediments.

The second step of the soil screening analysis is development of the source-specific soil exposure concentrations. The soil exposure concentration of a contaminant in an aggregate that represents the UCL_{95} developed using results of all the soil samples within the aggregate, or the maximum value if the UCL_{95} exceeds the maximum.

In the third step of the soil screening analysis, the soil exposure concentrations of all identified SRCs are compared with EPA generic soil screening levels (GSSLs). The GSSLs are set for Superfund sites for the migration to groundwater pathway (EPA 1996b). A dilution attenuation factor (DAF) of 3.0 was estimated following EPA guidelines (1996b) and applied to the GSSLs. As described in EPA Soil Screening Guidance documentation (EPA 1996b), contaminant dilution in groundwater is estimated at each unit from a unit-specific DAF. The DAF, which is defined as the ratio of soil leachate concentration to receptor point concentration, is minimally equal to 1. Dilution in groundwater is derived from a simple mixing zone equation (Equation 5-5) and relies upon estimation of the mixing zone depth (Equation 5-6).

$$DAF = 1 + \frac{(K_s \times i \times d)}{(I \times L)} \qquad \textbf{(5-5)}$$

where

DAF = dilution attenuation factor;
K_s = aquifer hydraulic conductivity (m/year) (see Table 5-1);
i = horizontal hydraulic gradient (m/m);
I = infiltration rate (m/year);

Table 5-1. Unit-Specific Parameters Used in SESOIL and AT123D Modeling for the Ramsdell Quarry Landfill

Parameters	Symbol	Units	Value	Source for Value
SESOIL				
Percolation Rate (Recharge Rate)	q	m/year	9.45E-02	HELP model results
Horizontal Area of Aggregate	A_p	sq. m	14,872	Estimated from soil aggregate
Intrinsic Permeability - clayey sand	k	cm^2	1.4E-10	Calibrated SESOIL model
Disconnectedness Index	c	unitless	10	Calibrated from SESOIL model
Freundlich Equation Exponent	n	unitless	1	SESOIL default
Fraction Organic Carbon	f_{oc}	unitless	2.60E-03	Geotech data at Load Line 1[a]
Bulk Density	ρ_b	kg/L	1.8	Geotech data at Load Line 1[a]
Porosity - total	n_T	unitless	0.32	Geotech data at Load Line 1[a]
Vadose Zone Thickness	Vz	m	4	Based on water level data
Leaching Zone Thickness	Th	m	3	Based on soil contamination and water level data
AT123D				
Aquifer Thickness	h	m	6	Load Line 1[a]
Hydraulic Conductivity in Saturated Zone	K_S	cm/s	1.7E-03	Site-specific slug test data
Hydraulic Gradient in Saturated Zone	I_S	m/m	8.00E-03	Groundwater surface map in work plan[b]
Effective Porosity	n_e	unitless	0.2	Assumed for sandstone
Distance to the Compliance Point	X	m	366	Shortest downgradient distance to stream boundary from source center
Dispersivity, longitudinal	α_L	m	36	Assumed
Dispersivity, transverse	α_T	m	12	0.3 α_L
Dispersivity, vertical	α_V	m	3.6	0.1 α_L
Retardation Factor	R_d	unitless	chemical-specific	See Table H-15

[a] Site-specific geotechnical data were not available for RQL, but geotechnical data from Load Line 1 were considered applicable due to the close proximity of RQL and Load Line 1.

[b] The hydraulic gradient was based on the observed gradient between MW-3 and RQLmw-007.

AT123D = Analytical Transient 1- ,2- ,3-Dimensional model.

HELP = Hydrologic Evaluation of Landfill Performance model.

SESOIL = Seasonal Soil Compartment model.

L = source length parallel to groundwater flow (m);
d = mixing zone depth (m), which is defined below.

$$d = \sqrt{0.0112 \times L^2} + d_a \times \left[1 - \exp\left(\frac{-L \times I}{K \times i \times d_a} \right) \right] \qquad \textbf{(5-6)}$$

where

d_a = aquifer thickness (m),
$d \leq d_a$.

As stated above, if the aquifer thickness is less than the calculated mixing zone depth, then the aquifer thickness is used for "d" in the DAF calculation. The GSSL is defined as the concentration of a contaminant in soil that represents a level of contamination below which there is no concern under CERCLA, provided conditions associated with GSSLs are met. However, it should be noted that the purpose of this screen is not to identify the contaminants that may pose risk at downgradient locations, but to target those contaminants that may pose the greatest problem if they are migrating from the site. When the GSSL for an SRC was not available from EPA (1996b), a calculated GSSL was developed using the following equation (EPA 1996b):

$$C_s = C_w \left\{ K_d + \frac{\theta_w + \theta_a K_H}{\rho_b} \right\} \qquad \textbf{(5-7)}$$

where

C_w = target groundwater concentration (mg/L),
C_s = calculated soil screening level (GSSL) (mg/kg),
K_d = soil adsorption coefficient (L/Kg),
K_H = Henry's Law Constant (unitless),
ρ_b = dry soil bulk density (kg/L),
θ_w = water-filled soil porosity (volume percent),
θ_a = air-filled soil porosity (volume percent).

Default values, as used by EPA (1996b) to develop the GSSLs, were used in the calculations. Non-zero MCLs or risk-based concentrations (RBCs) for groundwater were used for target groundwater concentrations. Based on this screening, only those constituents that exceeded their published or calculated GSSL multiplied by the DAF were identified as the initial (preliminary) CMCOPCs, based on leaching to groundwater. These initial CMCOPCs, illustrated on Table H-5 in Appendix H, include metals, explosive compounds, and VOCs.

In the fourth step, the initial CMCOPCs from RQL were further evaluated using fate and transport models provided in Section 5.5.

5.4.2 Limitations and Assumptions of Soil Screening Analysis

It is important to recognize that acceptable soil concentrations for individual chemicals are highly site-specific. The GSSLs used in this screening are based on a number of default assumptions chosen to be protective of human health for most site conditions (EPA 1996b). These GSSLs are expected to be more conservative than site-specific screening levels based on site geotechnical conditions. The conservative assumptions included in this analysis are: (1) no adsorption in the unsaturated zone or in the aquifer, (2) no biological or chemical degradation in the soil column or in the aquifer, and (3) contamination is uniformly distributed throughout the source. However, the GSSL does not incorporate the existence of contamination already present in the aquifer. In any case, to evaluate the contaminant migration potential from the source areas, a GSSL screen can be used as an effective tool.

5.5 FATE AND TRANSPORT MODELING

Contaminant fate and transport modeling is based on the conceptual model for RQL, as was discussed in Section 5.3. Seasonal Soil Compartment (SESOIL) modeling was performed for constituents identified as the initial CMCOPCs from the source (see Section 5.5.2). The modeling was performed to predict concentrations of a constituent in the leachate immediately beneath the selected source area just above the water table. If the predicted leachate concentration of a CMCOPC exceeded its MCL or RBC, then lateral migration using the Analytical Transient 1- ,2- ,3-Dimensional (AT123D) model (see Section 5.5.2) was performed to predict the groundwater concentrations at designated receptor locations. For SESOIL modeling, the receptor location identified for the source area was the water table immediately below the source. For AT123D modeling, the selected receptor was the closest suspected groundwater discharge point, an unnamed tributary north of RQL at its closest point downgradient of the source area (refer to Figure 2-3). This tributary eventually merges with drainage conveyances sourced within the Erie Burning Grounds and exits at the eastern boundary of RVAAP at Parshall Flume 534.

5.5.1 Modeling Approach

Contaminant transport in the vadose zone includes the movement of water and dissolved materials from the source area at RQL to groundwater. This occurs as rainwater infiltrates from the surface and percolates through the area of contamination into the saturated zone. The downward movement of water, driven by gravitational potential, capillary pressure, and other components of total fluid potential, mobilizes the contaminants and carries them through the vadose zone. Lateral transport is controlled by the regional groundwater gradient. Vertical transport to the water table and the horizontal transport through bedrock flow pathways to the downgradient receptor are illustrated in Figure 5-3.

The output of the contaminant fate and transport modeling is presented as the expected maximum concentration of modeled contaminants at the selected receptor locations. The modeling results allow prediction of the approximate locations of future maximum concentrations resulting from the integration of the contributions from multiple sources and different pathways. Once the leachate modeling for the source area was completed using the SESOIL model, the predicted maximum groundwater concentrations beneath the source area were determined using the AT123D model, and the concentrations were compared against the existing groundwater concentrations at the source area. The greater of the predicted or observed concentration in the groundwater was compared against the respective MCLs or RBCs. If the predicted or measured maximum groundwater concentrations were higher than the MCLs or RBCs, groundwater modeling was performed using the higher concentration as the source term concentration, thereby accounting for any secondary source, if present. If the predicted and actual concentrations were less than the MCLs or RBCs, the contaminant was eliminated from the list of CMCOPCs, and no further evaluations were performed.

5.5.2 Model Applications

The SESOIL model (GSC 1998) used for leachate modeling, when applicable, estimates pollutant concentrations in the soil profile following introduction via direct application and/or interaction with transport media. The AT123D model (Yeh 1992) is an analytical groundwater pollutant fate and transport

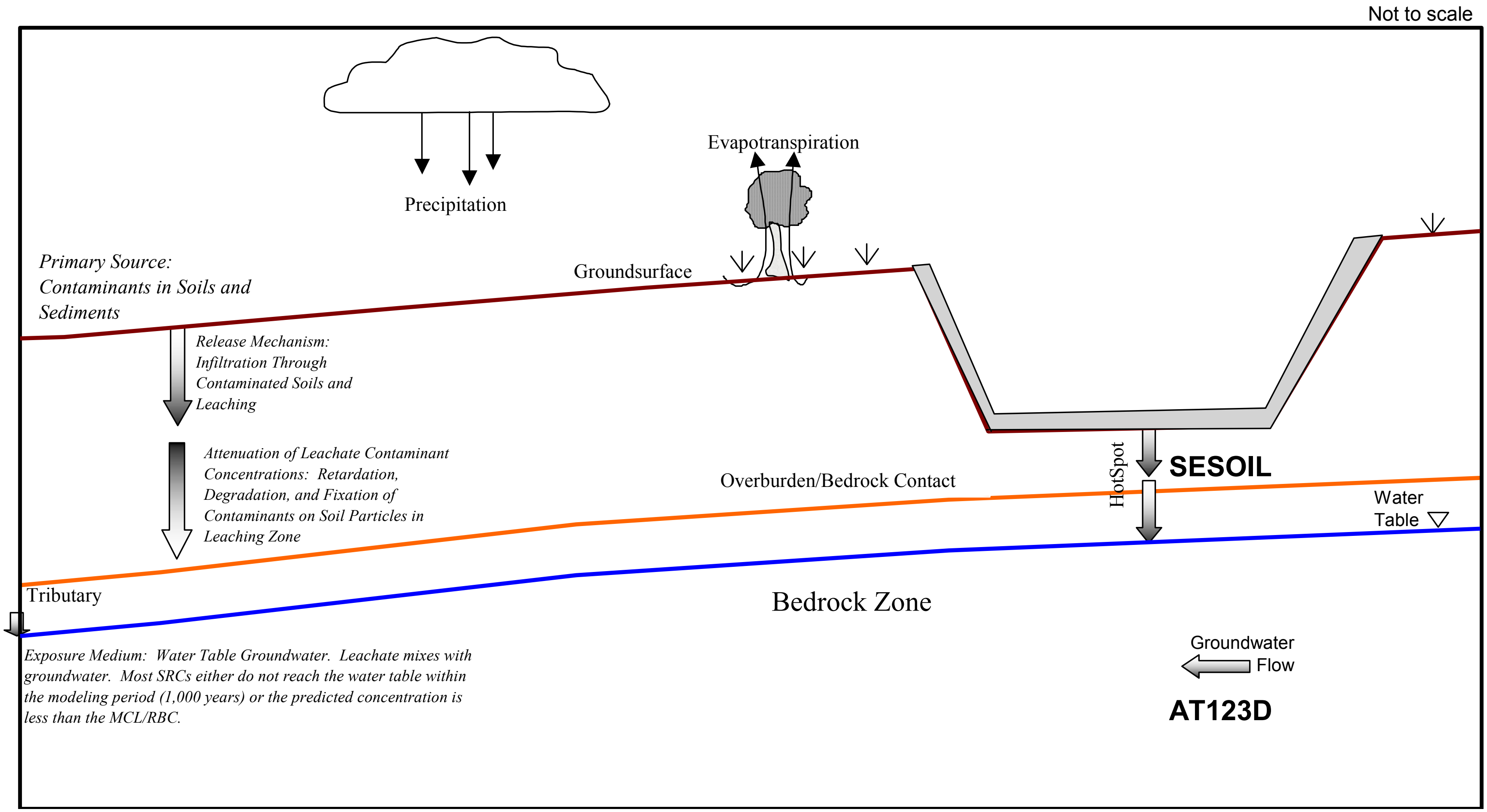


Figure 5-3. Contaminant Migration Conceptual Model for RQL

model. It computes the spatial-temporal concentration distribution of wastes in the aquifer system and predicts the transient spread of a contaminant plume through a groundwater aquifer. The application of both of these models is discussed in the following subsections.

5.5.2.1 SESOIL modeling

The SESOIL model defines the soil compartment as a soil column extending from the ground surface through the unsaturated zone and to the upper level of the saturated soil zone. Processes simulated in SESOIL are categorized in three cycles – the hydrologic cycle, sediment cycle, and pollutant cycle. Each cycle is a separate submodule in the SESOIL code. The hydrologic cycle includes rainfall, surface runoff, infiltration, soil-water content, evapotranspiration, and groundwater recharge. The pollutant cycle includes convective transport, volatilization, adsorption/desorption, and degradation/decay. A contaminant in SESOIL can partition in up to four phases (liquid, adsorbed, air, and pure). The sediment washload cycle includes erosion and sediment transport.

Data requirements for SESOIL are not extensive, utilizing a minimum of site-specific soil and chemical parameters and monthly or seasonal meteorological values as input. Output of the SESOIL model includes pollutant concentrations at various soil depths and pollutant loss from the unsaturated soil zone in terms of surface runoff, percolation to groundwater, volatilization, and degradation. The mathematical representations in SESOIL generally consider the rate at which the modeled processes occur, the interaction of different processes with each other, and the initial conditions of both the waste area and the surrounding subsurface matrix material. SESOIL simulation for a contaminant was performed over a 1,000-year period. The period was selected considering the voluminous output and the lengthy time required to complete a simulation for a longer period of time. Also, EPA suggests a screening value of 1,000 years to be used due to the higher uncertainty associated with predicting conditions beyond that time frame.

A two-step process was implemented for the leaching model: (1) estimation of leaching potential of initial CMCOPCs using an empirical equation based on Darcy's Law, and (2) application of SESOIL to initial CMCOPCs passing the empirical screen to identify those constituents likely to reach the water table at concentrations exceeding MCLs or RBCs. The initial CMCOPCs at the selected source were evaluated with respect to a travel time of 1,500 years to identify leaching potential. This process was intended to refine the list of constituents requiring modeling through use of a conservative empirical tool in addition to the GSSL screen. The empirical screening step is considered highly conservative for RQL because of thin soil thicknesses and the fact that the equation does not factor in diffusion coefficients. The travel time is the time required by a contaminant to travel from the base of its contamination to the water table. The estimated travel time for each initial CMCOPC to reach the water table is determined using the following equation:

$$T_r = \frac{T_h \times R_d}{V_p} \qquad \textbf{(5-8)}$$

where

T_t = leachate travel time (year),
T_h = thickness of attenuation zone (ft),
R_d = retardation factor (dimensionless) (Equation 5-2),
V_p = pore water velocity (ft/year).

and

$$V_p = \frac{I}{\theta} \tag{5-9}$$

where

I = infiltration rate (ft/year),
θ = fraction of total porosity that is filled by water.

If the source depth for a constituent is equal to the thickness of the vadose zone, the constituent is determined to have a travel time equal to zero using the above equations (i.e., no leaching zone). The estimated travel time was then compared to a screening value. If the travel time for a constituent from a source area exceeded 1,500 years, then the constituent was eliminated from the list of CMCOPCs selected for SESOIL modeling. Initial CMCOPCs with travel times less than 1,500 years were selected for modeling using SESOIL.

Details of the model layers utilized in this modeling are presented in Tables H-9 and H-10 of Appendix H. The model was calibrated against the percolation rate by varying the intrinsic permeability and by keeping all other site-specific geotechnical parameters fixed. The final site-specific hydrogeologic parameter values used in this modeling are shown in Table 5-1. The intrinsic permeability was derived during calibration of the model to a percolation rate of 0.09 m/year. The chemical-specific parameters are presented in Appendix H (Table H-8). The distribution coefficients (K_ds) for metals were obtained from EPA's Soil Screening Guidance Document (EPA 1996b) unless stated otherwise. The K_ds for organic compounds were estimated from organic carbon-based water partition coefficients (K_{oc}) using the relationship $K_d = (f_{oc})(K_{oc})$, where f_{oc} = soil organic carbon content as mass fraction obtained from site-specific measurements and K_{oc} values were obtained from EPA's Soil Screening Guidance Document (EPA 1996b), unless stated otherwise. Biodegradation rates are not applicable for the inorganic CMCOPCs. The most conservative values found in the literature (Howard et al. 1991) were used for organic CMCOPCs; however, biodegradation values could not be found in literature for nitroglycerin, RDX, 2-methylnaphthalene and carbazole (Table H-3). The constituents selected for SESOIL modeling are listed in Table 5-2.

5.5.2.2 AT123D modeling in the saturated zone

The fate and transport processes accounted for in the AT123D model include advection, dispersion, adsorption/retardation, and decay. This model can be used as a tool for estimating the dissolved concentration of a chemical in three dimensions in the groundwater resulting from a mass release over a source area (point, line, area, or volume source). The model can handle instantaneous, as well as continuous, source loadings of chemicals of interest at the site. AT123D is frequently used by the scientific and technical community to perform quick and conservative estimates of groundwater plume movement in space and time. SESOIL and AT123D are linked in a software package (RISKPRO) so that mass loading to the groundwater predicted by SESOIL can be directly transferred to AT123D. Therefore, AT123D was chosen to predict the future receptor concentrations for the contaminants.

The hydrogeologic parameter values used in this modeling are shown in Table 5-1. The chemical-specific parameters are presented in Appendix H (Table H-15). A discussion of model assumptions and limitations is presented in Section 5.5.4. The constituents selected for this modeling are listed in Table 5-3, along with the results of the modeling. The CMCOPCs in this table represent all of the constituents that were identified as final CMCOPCs based on leachate modeling (SESOIL), plus any additional constituents currently observed in groundwater exceeding their respective MCL or RBC. Constituents for which the predicted maximum groundwater concentration exceeded the MCL or RBC at a receptor location were identified as the constituent migration contaminants of concern (CMCOCs).

Table 5-2. Summary of Leachate Modeling Results for the Ramsdell Quarry Landfill

Initial CMCOPC	RME 0 to 1 ft (mg/kg)	Predicted $C_{leachate,max}$ Beneath the Source (mg/L)	Predicted Tmax (years)	Predicted $C_{gw,max}$ At the Source[a] (mg/L)	Observed $C_{gw,max}$ Downgradient of Source (mg/L)	MCL/RBC (mg/L)	Final CMCOPC[b]
Explosives							
1,3-Dinitrobenzene	4.43E-01	4.14E-01	2	1.38E-01	NF	3.65E-03	Yes
2,4-Dinitrotoluene	6.40E-02	9.35E-03	4	3.12E-03	NF	7.30E-02	No
2,6-Dinitrotoluene	8.43E-01	1.77E-01	3	5.88E-02	NF	3.60E-02	Yes
Nitroglycerin	2.41E+01	3.09E+01	6	1.03E+01	NF	4.80E-03	Yes
RDX	2.07E-01	8.19E-01	2	2.73E-01	NF	6.10E-04	Yes
Metals							
Antimony	2.53E+00	3.59E-02	437	1.20E-02	5.80E-04	6.00E-03	Yes
Arsenic	1.60E+01	3.55E-01	284	1.18E-01	6.80E-03	1.00E-02	Yes
Cadmium	1.80E+00	1.47E-02	719	4.89E-03	7.00E-04	5.00E-03	No
Chromium	3.72E+01	1.26E+00	187	4.20E-01	NF	1.00E-01	Yes
Mercury	3.38E-01	3.01E-04	445	1.00E-04	NF	2.00E-03	No
Nickel	3.78E+01	3.68E-01	629	1.23E-01	3.06E-01	7.30E-01	No
Thallium	6.05E-01	5.44E-03	689	1.81E-03	NF	2.00E-03	No
Organics-Semivolatile							
2-Methylnaphthalene	6.34E+00	1.55E-01	179	5.18E-02	NF	1.22E-01	No
Carbazole	4.33E+01	3.17E+00	88	1.06E+00	NF	3.36E-03	Yes
Dibenzofuran	2.56E+01	1.00E-11	146	3.33E-12	NF	2.43E-02	No

[a] The concentration was calculated using a dilution attenuation factor = 3.

[b] The final CMCOPC was identified comparing predicted/observed concentration in groundwater to the MCL/RBC. A constituent is a final CMCOPC if its predicted/observed concentration in groundwater exceeds its MCL/RBC within 1,000 years.

CMCOPC = Contaminant migration contaminant of potential concern.
NF = Not found.
MCL = Maximum contaminant level.
RBC = Risk-based concentration (EPA Region 9 preliminary remediation goals).
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RME = Reasonable maximum exposure.

Table 5-3. Summary of Groundwater Modeling Results for the Ramsdell Quarry Landfill

Final CMCOPC	Source Concentration (mg/L)		Receptor Concentration Unnamed Tributary (mg/L)		Observed $C_{gw,max}$ (mg/L)	MCL/RBC (mg/L)	CMCOC
Explosives							
1,3-Dinitrobenzene	9.70E-03	b	1.48E-06	b	NF	3.65E-03	No
2,6-Dinitrotoluene	4.23E-03	b	1.57E-08	b	NF	3.60E-02	No
Nitroglycerin	2.10E+00	b	4.23E-01	b	NF	4.80E-03	Yes
RDX	4.46E-02	b	1.72E-02	b	NF	6.10E-04	Yes
Metals							
Antimony	1.20E-02	a	0.00E+00	d	5.80E-04	6.00E-03	No
Arsenic	1.18E-01	a	0.00E+00	d	6.80E-03	1.00E-02	No
Chromium	4.20E-01	a	0.00E+00	d	NF	1.00E-01	No
Manganese	6.17E+00	c	0.00E+00	d	6.17E+00	8.76E-01	No
Organics-Semivolatile							
Carbazole	2.19E-01	b	3.21E-02	b	NF	3.36E-03	Yes

[a] The concentration was calculated using a dilution attenuation factor = 3.
[b] The concentration was re-calculated using SESOIL-AT123D model.
[c] The concentration was observed in groundwater.
[d] The concentration was set to 0 considering a travel time exceeding 1,500 years.
CMCOC = Contaminant migration contaminant of concern.
CMCOPC = Contaminant migration contaminant of potential concern.
MCL = Maximum contaminant level.
NF = Not found.
RBC = Risk-based concentration (EPA Region 9 preliminary remediation goals).
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.

5.5.3 Modeling Results

SESOIL modeling was performed for initial CMCOPCs that are expected to reach the water table within 1,500 years based on the empirical screen discussed previously (Table 5-2). The modeling was performed for 1,3-DNB; 2,4-DNT; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; cadmium; chromium; mercury; nickel; thallium; 2-methylnaphthalene; carbazole; and dibenzofuran. Table 5-2 presents the predicted peak leachate and groundwater concentrations beneath the source area and the corresponding time for peak leachate concentrations. The predicted groundwater concentrations were developed by dividing the predicted peak leachate concentration by the site-specific DAF (see Section 5.4). In addition, this table presents, for comparison, the current maximum observed concentrations in the groundwater within the AOC and drinking water MCLs or RBCs (if no MCL is available). The table shows that 1,3-DNB; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; chromium; and carbazole were predicted to exceed MCLs or RBCs beneath the source area. In addition, manganese was observed to exceed its RBC beneath the area (Table H-12 in Appendix H). These constituents were selected as the final CMCOPCs for lateral migration.

Table 5-3 shows the final CMCOPCs selected for lateral migration modeling using AT123D. However, before performing AT123D modeling, travel times for migration to the nearest downgradient receptor location [approximately 365 m (1,200 ft) from the source] were estimated using Equation 5-8. The pore water velocity in this case was estimated using Darcy's law (i.e., $Vp = K.i/n_e$, where K = saturated hydraulic conductivity, I = lateral hydraulic gradient, and n_e = effective porosity). If the travel time for a CMCOPC exceeded 1,500 years, then that CMCOPC was not modeled using AT123D and a concentration of zero at the receptor was assumed. For the remaining CMCOPCs, AT123D modeling was performed using contaminant loading from SESOIL, except for manganese. For manganese, AT123D modeling was calibrated to the maximum observed concentration. Table 5-3 presents the predicted groundwater concentration at the selected downgradient receptor locations. Of these constituents, nitroglycerin, RDX, and carbazole were predicted to reach the unnamed tributary north of RQL at concentrations exceeding MCLs or RBCs within a 1,000-year time period and were identified as CMCOCs.

5.5.4 Limitations/Assumptions

A conservative modeling approach was used, which may overestimate the contaminant concentration in the leachate for migration from observed soil concentrations. Listed below are important assumptions used in this analysis.

- The use of K_d and R_d to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid- and solution-phase concentrations and that the relationship is linear and reversible.
- The K_d values used in this analysis for all the CMCOPCs represent literature or calculated values and may not represent the site conditions.
- Flow and transport in the vadose zone is one-dimensional (i.e., only in the vertical direction).
- Initial condition is disregarded in the vadose zone modeling.
- Flow and transport are not affected by density variations.
- A realistic distribution of soil contamination is not considered.
- No seasonal variation in the groundwater flow direction was considered.
- Contaminant migration from the source to the compliance point is the shortest line.

The inherent uncertainties associated with using these assumptions must be recognized. K_d values are highly sensitive to changes in the major chemistry of the solution phase. Therefore, it is important that the values be measured or estimated under conditions that will represent as closely as possible those of the contaminant plume. It is also important to note that the contaminant plume will change over time and will be affected by multiple solutes that are present at the site. Projected organic concentrations in the aquifer are uncertain because of the lack of site-specific data on constituent decay in the vadose zone, as well as in the saturated zone. Use of literature values (particularly partition coefficients) may produce either over- or underestimation of constituent concentrations in the aquifer. In this sense, the modeling may not be conservative. Deviations of actual site-specific parameter values from assumed literature values may significantly affect contaminant fate predictions.

The effects of heterogeneity, anisotropy, and spatial distribution of fractures are not addressed in these simulations. The present modeling study using SESOIL and AT123D does not address the effects of flow and contaminant transport across interfaces in rapidly varying heterogeneous media.

Conceptually, the water-table depth was assumed to be 4 ft bgs below the bottom of the quarry (SESOIL modeling depth). The saturated groundwater flow was assumed to occur through bedrock (Figure 5-3). As noted in Chapter 2.0, water levels may equal the bottom elevation of the quarry during very wet periods. Given AT123D limitation, the hydraulic conductivity field for the saturated zone was assumed homogeneous, and its geometric mean value of 1.6E-3 cm/sec based on the slug-test results (Section 2.4.2) was used in this modeling. Noting the conductivity to range from 2.00E-04 to 9.20E-03 cm/sec, the predicted concentrations appear to represent a mean condition within a range of expected concentrations. The range appears to be an order of magnitude, suggesting the associated uncertainty to be significant.

For AT123D modeling, the key input parameters are hydraulic conductivity (K_s), hydraulic gradient (I_s), effective porosity (n_e), and K_d. The K_s, I_s, and n_e work as a lumped parameter controlling the seepage velocity $V_s = K_s*I_s/n_e$. The impact (sensitivity) of K_d is discussed above. The hydraulic gradient is noted to vary over a narrow range below the quarry (Figure 2-4). Therefore, the impact of hydraulic gradient is expected to be less than that of K_s. In addition, a change in groundwater flow direction will affect the travel distance from the source to the compliance point. Here, groundwater was assumed to flow from the source to the compliance point along the shortest line. This assumption is expected to produce conservative results. The impact of n_e can be significant given the presence of fractures in the Sharon Conglomerate (Section 2.3.1.2).

5.6 SUMMARY AND CONCLUSIONS

Based on site characterization and monitoring data, metals, organics, and explosives-related compounds exist in the surface soil at RQL. Although explosives and organics (except carbon disulfide) were not detected in groundwater during the Phase I RI, fate and transport modeling using RQL as the selected source indicate that some of these contaminants may leach from contaminated soils into the groundwater beneath the source in the future. Migration of many of the constituents is, however, likely to be attenuated because of moderate to high retardation factors. Conclusions of the leachate and groundwater modeling are as follows.

- 1,3-DNB; 2,4-DNT; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; cadmium; chromium; mercury; nickel; thallium; 2-methylnaphthalene; carbazole; and dibenzofuran were identified as initial CMCOPCs for RQL based on soil screening analysis.

- 1,3-DNB; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; chromium; and carbazole were identified as final CMCOPCs for RQL based on source loading predicted by the SESOIL modeling. In addition, manganese was observed to exceed its secondary MCL, and it was identified as a final CMCOPC.

- Nitroglycerin, RDX, and carbazole were identified as CMCOCs based on AT123D modeling. The maximum groundwater concentrations of the constituents were predicted to exceed MCLs or RBCs at the unnamed tributary north of Ramsdell Quarry at the closest point downgradient of the AOC within a 1,000-year time period.

6.0 HUMAN HEALTH RISK ASSESSMENT

6.1 INTRODUCTION

This human health risk assessment (HHRA) documents the potential health risks to humans resulting from exposure to contamination within RQL. This HHRA is conducted as part of the Phase I RI and is based on the methods from the *RVAAP's Facility-wide Human Health Risk Assessor Manual* (FWHHRAM) (USACE 2004b).

The objective of this HHRA is to evaluate and document the potential risks to human health associated with current and potential future exposures to contaminants if no remedial action is taken. Thus, this assessment represents the risks for the "no-action" alternative in a FS.

This HHRA is conducted per the FWHHRAM (USACE 2004b). The methodology presented in the FWHHRAM is based on *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989b and 1991b) and additional methodology taken from *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA 2002a); *Exposure Factors Handbook* (EPA 1997b); Integrated Risk Information System (IRIS) (EPA 2005, updated approximately monthly); and Health Effects Assessment Summary Tables (HEAST) (EPA 1997c). The inorganic and organic COPCs identified in this HHRA are quantitatively analyzed (when possible) to characterize the potential risks to human health from exposure to these contaminants. The results of the HHRA are used to (1) document and evaluate risks to human health; (2) determine the need, if any, for remedial action; and (3) identify chemicals of concern (COCs) that may require the development of chemical-specific remediation levels.

This risk assessment is organized into six major sections. The screening process used to identify COPCs is discussed in Section 6.2. The exposure assessment, which is performed to identify the exposure pathways by which receptors may be exposed to contaminants and calculate potential intakes, is presented in Section 6.3. The toxicity assessment for RQL COPCs is presented in Section 6.4. The results of the risk characterization are presented in Section 6.5 and the uncertainty analysis is presented in Section 6.6. Remedial goal options (RGOs) are presented in Section 6.7, and the conclusions of the HHRA are summarized in Section 6.8.

6.2 DATA EVALUATION

The purpose of the data evaluation is to develop a set of chemical data suitable for use in the HHRA. Data are evaluated to establish a list of COPCs using screening criteria. Only the results of discrete sampling are used in the risk assessment. Multi-increment sampling was conducted at Ramsdell Quarry to evaluate its application in field investigations. Multi-increment sampling results are not used in the risk assessment.

This section provides a description of the data evaluation process used to identify COPCs for RQL. The data evaluation process is conducted in accordance with the FWHHRAM (USACE 2004b). The purpose of the screening HHRA data evaluation screening process is to eliminate chemicals for which no further risk evaluation is needed.

Data collected at RQL are aggregated by environmental medium (e.g., surface soil). Samples included in the HHRA data sets for groundwater, surface soil, sediment, and surface water are listed in Tables 6-1 through 6-4, respectively. A description of the media for which human receptors are potentially exposed follows.

Table 6-1. Human Health Risk Assessment Data Set for Groundwater

Station	Sample ID
RQLmw-012	RQ0139
RQLmw-013	RQ0140
RQLmw-014	RQ0141
RQLmw-015	RQ0142
RQLmw-016	RQ0143
RQLmw-017	RQ0144

Table 6-2. Human Health Risk Assessment Data Set for Surface Soil

Station	Sample ID	Depth (ft BGS)
RQL-024	RQ0124	0 to 1
RQL-025	RQ0125	0 to 1
RQL-026	RQ0126	0 to 1
RQL-027	RQ0127	0 to 1
RQL-028	RQ0128	0 to 1
RQL-029	RQ0129	0 to 1
RQL-030	RQ0130	0 to 1
RQL-031	RQ0131	0 to 1
RQL-032	RQ0132	0 to 1
RQL-033	RQ0133	0 to 1
RQLsd-012	RQ0064	0 to 0
RQLsd-012	RQ0023	0 to 0.5
RQLsd-013	RQ0032	0 to 0.5
RQLsd-013	RQ0033	0.5 to 1.25
RQLsd-019	RQ0029	0 to 0.5

BGS = Below ground surface.

Table 6-3. Human Health Risk Assessment Data Set for Sediment

Station	Sample ID	Depth (ft BGS)
RQLsd-014	RQ0035	0 to 0.5
RQLsd-015	RQ0044	0 to 0.5
RQLsd-018	RQ0026	0 to 0.5
RQLsd-022	RQ0038	0 to 0.5
RQLsd-023	RQ0041	0 to 0.5

BGS = Below ground surface.

Table 6-4. Human Health Risk Assessment Data Set for Surface Water

Station	Sample ID
RQLsw-012	RQ0018
RQLsw-013	RQ0019
RQLsw-014	RQ0020
RQLsw-015	RQ0021
RQLsw-015	RQ0073
RQLsw-015	RQ0123
RQLsw-015	RQ0116
RQLsw-015	RQ0109
RQLsw-015	RQ0102

- Surface soil is defined as soil coming from 0 to 1 ft bgs (shallow surface soil) for all receptors except the National Guard Trainee. Surface soil is defined as 0 to 4 ft bgs (deep surface soil) for the National Guard Trainee; however, no samples are available below 1 ft bgs due to the presence of shallow bedrock. For this HHRA, surface soil samples from 2003, as well as dry sediment samples from 1998 to 1999, are used to characterize surface soil at RQL. Three sediment sampling locations [RQLsd-012(17), RQLsd-013(20), and RQLsd-019] were included in the surface soil data set because these stations tended to be dry much of the time.

- Groundwater data from the 2003 sampling event are evaluated in this HHRA.

- Shallow bedrock precludes the collection of subsurface samples; therefore, subsurface soil is not evaluated in this HHRA. Bedrock is exposed across much of the site. Measured depth to bedrock ranged from 0 to < 5 ft bgs with the deeper depths (i.e., approaching 5 ft) occurring at the perimeter of the site.

- Surface water and subaqueous sediment samples collected from 1998 to 1999 are used to characterize risks from these media.

RQL encompasses approximately 14 acres and is evaluated as a single exposure unit (EU). Evaluation as a single EU is appropriate for the potential current and future exposures at this site (i.e., restricted access with occasional visits by security or maintenance personnel; see Section 6.3).

Section 6.2.1 provides a summary of the COPC selection process and the data assumptions used during that process. Section 6.2.2 presents the results of the COPC screening process.

6.2.1 Chemical of Potential Concern Screening

This section provides a description of the screening process used to identify COPCs and the data assumptions used in the process.

The data evaluation consists of five steps, per the FWHHRAM (USACE 2004b): (1) a data quality assessment (DQA), (2) screening of essential human nutrients, (3) risk-based screening, and (4) background screening. No frequency-of-detection/WOE screening (the fifth data evaluation step) is performed because fewer than 20 samples are available for the groundwater, surface soil, sediment, and surface water data sets.

1. **Data Quality Assessment** – Analytical results were reported by the laboratory in electronic form and loaded into a RQL database. Site data were then extracted from the database so that only one result is used for each station and depth sampled. QC data, such as sample splits and duplicates, and laboratory re-analyses and dilutions were not included in the determination of COPCs for this risk assessment. Field screening data that were considered in the evaluation of nature and extent of contamination at RQL are not included in the data set for the risk assessment. Samples rejected in the validation process are also excluded from the risk assessment. The percentage of rejected data is estimated to be less than 1%. A complete summary of data quality issues is presented in the DQA Appendix of this report (see Appendix F).

2. **Essential Nutrients** – Chemicals that are considered essential nutrients (i.e., calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the human food supply and are often added to foods as supplements. EPA recommends that these chemicals not be evaluated as COPCs so long as they are (1) present at low concentrations (i.e., only slightly elevated above naturally occurring levels) and (2) toxic at very high doses (i.e., much higher than those that could be associated with contact at the site) (EPA 1989b). Recommended daily allowance (RDA) and recommended daily intake (RDI) values are available for seven of these metals. Based on these RDA/RDI values, a receptor ingesting 100 mg of soil/sediment per day would receive less than the RDA/RDI of calcium, magnesium, phosphorous, potassium, and sodium, even if the soil/sediment consisted of the pure mineral (i.e., soil/sediment concentrations > 1,000,000 mg/kg). Receptors ingesting 100 mg of soil/sediment per day would require soil/sediment concentrations of 1,500 mg/kg of iodine and 100,000 to 180,000 mg/kg of iron to meet their RDA/RDI for these metals. Receptors ingesting 1 L of groundwater/surface water per day would require water concentrations of 1,000; 0.15; 10 to 18; 310 to 400; 3,500; 700; and 2,400 mg/L of calcium, iodine, iron, magnesium, potassium, phosphorous, and sodium, respectively, to meet their RDA/RDI. Concentrations of essential nutrients do not approach these levels at RQL with the exception of iron in unfiltered surface water, which exceeds three of nine samples. Surface water is not used as a potable water source by any receptor; thus, these constituents are not addressed as COPCs in this HHRA.

3. **Risk-based Screen** – The objective of this evaluation is to identify COPCs that may pose a potentially significant risk to human health. The risk-based screening values are conservative values published by EPA. The MDC of each chemical in groundwater, surface soil, sediment, and surface water is compared to the appropriate risk-based screening value. Chemicals detected below these concentrations are screened from further consideration. Detected chemicals without risk-based screening values are not eliminated from the COPC list. The risk-based screening values are described in Section 6.2.1.1.

4. **Background Screen** – For each inorganic constituent detected, concentrations in the RQL samples are screened against available, naturally occurring background levels (see Section 4.1). This screening step, which applies only to the inorganics, is used to determine if detected inorganics are site related or naturally occurring. If the MDC of a constituent exceeds the background value, the constituent is considered AOC-related. All detected organic compounds are considered to be above background. Inorganic chemicals whose MDCs are below background levels are eliminated from the COPC list. Background screening values are described in Section 6.2.1.2.

6.2.1.1 Risk-based screening values

The risk-based screening values are conservative values published by EPA.

- For surface soil and sediment, a conservative screen is performed using the most current residential PRGs published by EPA Region 9 (EPA 2004). To account for the potential effects of multiple chemicals, PRGs based on non-cancer endpoints are divided by 10. These screening values are very conservative [based on a 10^{-6} risk level and a hazard quotient (HQ) of 0.1]. Region 9 PRGs can be found on the EPA Region 9 World Wide Web site (http://www.epa.gov/region09/waste/sfund/prg/index.html).

- Groundwater and surface water data are screened using the EPA Region 9 tap water PRGs (EPA 2004), which are also available at http://www.epa.gov/region09/waste/sfund/prg/index.html.

6.2.1.2 Background screening values

This RQL Phase I RI does not include determination of background data specific to RQL. Analytical results are screened against the final facility-wide background values for RVAAP, published in the *Final Phase II Remedial Investigation Report for Winklepeck Burning Grounds at Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2001b). Background values for soil are available for two soil depths: surface (0 to 1 ft bgs) and subsurface (1 to 12 ft bgs). The surface soil data at RQL are compared against the surface soil background values from USACE 2001b. Based on the depth to groundwater at RQL, groundwater data are compared against bedrock background values from USACE 2001b.

6.2.1.3 COPC screening assumptions

The following assumptions, used in the development of COPCs for the HHRA, are noted:

- Chemicals not detected in a medium are not considered to be COPCs.

- Physical chemical data (e.g., alkalinity, pH, etc.) are not considered to be COPCs for RQL.

- Because all samples were evaluated in the laboratory for chromium (and not hexavalent chromium), total chromium is evaluated conservatively by screening against the EPA Region 9 PRGs for hexavalent chromium. This is a conservative assumption since (1) hexavalent chromium is more toxic than trivalent chromium (the only other form of chromium with available toxicity information), and (2) hexavalent chromium is a less commonly occurring form of the metal.

6.2.2 Chemical of Potential Concern Screening Results

The COPC screening results are presented in Appendix L for groundwater (Table L-1), surface soil (Table L-2), sediment (Table L-3), and surface water (Table L-4). These tables include

- summary statistics, including frequency of detection, range of detected concentrations, arithmetic average concentration, and UCL_{95} on the mean concentration;

- all screening values (PRGs and background concentrations, as appropriate); and

- final COPC status.

Screening results are summarized across all media in Table 6-5. A discussion of these results for each medium follows.

6.2.2.1 Groundwater COPCs

Screening to determine groundwater COPCs at RQL is shown in Table L-1 and summarized in Table 6-5. As seen, a total of three metals are identified as groundwater COPCs: arsenic, lead, and manganese. This screen was performed only on Phase I RI data obtained from wells RQLmw-012 through -017.

6.2.2.2 Surface soil COPCs

Screening to determine surface soil COPCs at RQL is shown in Table L-2 and summarized in Table 6-5. As seen, a total of 32 COPCs were identified within the surface soil aggregate. The 32 surface soil COPCs include:

- 9 inorganics (aluminum, antimony, arsenic, cadmium, chromium, copper, lead, thallium, and vanadium);

- 6 explosives (1,3-DNB; 2,4,6-TNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitroglycerin); and

- 17 SVOCs [2-methylnaphthalene, acenaphthylene, benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*g,h,i*)perylene, benzo(*k*)fluoranthene, carbazole, chrysene, dibenz(*a,h*)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-*cd*)pyrene, naphthalene, phenanthrene, and pyrene].

Based on lack of toxicity information (see Section 6.3), 7 of these 32 surface soil COPCs are classified as qualitative COPCs [sulfate; 2-amino-4,6-DNT; 4-amino-2,6-DNT; nitroglycerin; acenaphthylene; benzo(*g,h,i*)perylene; and phenanthrene]; risks and hazards cannot be quantified for these 7 COPCs. All seven of these chemicals were retained as COPCs based on having no residential soil screening PRG values.

Note that one sample (RQL-026) highly influences the determination of surface soil COPCs, as the MDC comes from this one sample for 25 of the 32 COPCs; the MDCs for all 17 SVOCs that are surface soil COPCs are from RQL-026, as are 3 of the 9 metal COPCs and 5 of the 6 explosive COPCs. For many of these COPCs, the next largest concentration is 1 to 2 orders of magnitude lower than the concentration detected in sample RQL-026.

6.2.2.3 Sediment COPCs

Screening to determine sediment COPCs at RQL is shown in Table L-3 and summarized in Table 6-5. A total of 11 COPCs were identified for sediment. The 11 sediment COPCs include:

- 7 inorganics (aluminum, arsenic, cadmium, chromium, manganese, thallium, and vanadium),
- 1 explosive (nitrocellulose), and
- 3 SVOCs [benzo(*a*)pyrene, benzo(*g,h,i*)perylene, and phenanthrene].

Based on lack of toxicity information (see Section 6.3), 3 of these 11 sediment COPCs are classified as qualitative COPCs [nitrocellulose; benzo(*g,h,i*)perylene; and phenanthrene]; risks and hazards cannot be quantified for these 3 COPCs. All three of these chemicals were retained as COPCs because they have no residential soil screening PRG values.

Table 6-5. COPCs for each Medium at Ramsdell Quarry Landfill

COPC	Groundwater	Surface Soil	Sediment	Surface Water
Quantitative COPCs[a]				
Inorganics				
Aluminum		X	X	X
Antimony		X		
Arsenic	X	X	X	X
Cadmium		X	X	
Chromium[b]		X	X	
Copper		X		
Lead[c]	X	X		X
Manganese	X		X	X
Thallium		X	X	
Vanadium		X	X	X
Organics				
1,3-Dinitrobenzene		X		
2,4,6-Trinitrotoluene		X		
2,6-Dinitrotoluene		X		
2-Methylnaphthalene		X		
Aldrin				X
Benz(*a*)anthracene		X		
Benzo(*a*)pyrene		X	X	
Benzo(*b*)fluoranthene		X		
Benzo(*k*)fluoranthene		X		
Carbazole		X		
Chrysene		X		
Dibenz(*a,h*)anthracene		X		
Dibenzofuran		X		
Fluoranthene		X		
Fluorene		X		
Indeno(1,2,3-*cd*)pyrene		X		
Methylene Chloride				X
Naphthalene		X		
Pyrene		X		
Tetrachloroethene				X
Qualitative COPCs[d]				
Inorganics				
Sulfate				X
Qualitative COPCs[d]				
Organics				
2-Amino-4,6-dinitrotoluene		X		
4-Amino-2,6-dinitrotoluene		X		
Acenaphthylene		X		
Benzo(*g,h,i*)perylene		X	X	
Nitrocellulose			X	
Nitroglycerin		X		
Phenanthrene		X	X	

[a] Quantitative COPCs have approved toxicity values that allow for further quantitative evaluation in the human health risk assessment.
[b] Chromium is conservatively evaluated with the toxicity values for hexavalent chromium.
[c] Although lead does not have toxicity values for which to quantify risks and/or hazards, it can be evaluated quantitatively with blood lead models from the U. S. Environmental Protection Agency.
[d] Qualitative COPCs do not have approved toxicity values that allow for further quantitative evaluation in the human health risk assessment.
COPC = Chemical of potential concern.
X = Chemical is a COPC for this medium.

6.2.2.4 Surface water COPCs

Screening to determine surface water COPCs at RQL is shown in Table L-4 and summarized in Table 6-5. A total of nine COPCs were identified for surface water. The nine surface water COPCs include:

- six inorganics (aluminum, arsenic, lead, manganese, sulfate, and vanadium),
- one pesticide (aldrin), and
- two VOCs (methylene chloride and tetrachloroethene).

Based on lack of toxicity information (see Section 6.3), one of these nine surface water COPCs is classified as a qualitative COPC (sulfate); risks and hazards cannot be quantified for this COPC. Sulfate was retained as a COPC because it has no tap water screening PRG value.

Each of the two VOCs retained as COPCs were detected in only one surface water sample; however, due to the relatively small data set (samples), these chemicals could not be eliminated based on low frequency of detection.

6.2.2.5 Summary of COPCs

Table 6-5 summarizes COPCs across all media (groundwater and surface soil). As seen, a total of 38 COPCs are identified, including

- 11 inorganics (aluminum, antimony, arsenic, cadmium, chromium, copper, lead, manganese, sulfate, thallium, and vanadium),

- 7 explosives (1,3-DNB; 2,4,6-TNT; 2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; and nitroglycerin), and

- 18 SVOCs [2-methylnaphthalene, cenaphthylene, aldrin, benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*g,h,i*)perylene, benzo(*k*)fluoranthene, carbazole, chrysene, dibenz(*a,h*)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-*cd*)pyrene, naphthalene, phenanthrene, and pyrene], and

- 2 VOCs (methylene chloride and tetrachloroethene).

6.3 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to estimate the magnitude, frequency, and duration of potential human exposure to COPCs. The four primary steps of the exposure assessment are to

1. identify current and future land use;
2. identify potentially exposed populations, exposure media, and exposure pathways;
3. calculate exposure point concentrations (EPCs); and
4. estimate each receptor’s potential intake of each COPC.

The output of the exposure assessment is used in conjunction with the output of the toxicity assessment (Section 6.4) to quantify risks and hazards to receptors in the risk characterization (Section 6.5).

6.3.1 Current and Future Land Use

RQL includes environmentally sensitive areas (i.e., wetlands), a closed landfill, and may contain MEC and, as a result, is classified as “Restricted Access” and will remain Restricted Access in the future. Ramsdell Quarry is closed to all normal training and administrative activities. Surveying, sampling, and other essential security, safety, natural resources management, and other directed activities may be conducted at Ramsdell Quarry only after authorized personnel have been properly briefed on potential hazards/sensitive areas. Authorized personnel must escort individuals that are unfamiliar with the hazards/restrictions at all times while in the restricted area (USACE 2004b). In addition to MEC concerns, the requirement to protect the landfill cap precludes changes in future land use.

6.3.2 Potentially Exposed Populations, Exposure Media, and Exposure Pathways

Potentially contaminated media at RQL are surface soil (0 to 1 ft bgs), groundwater, surface water, and sediment.

Given the restricted access to Ramsdell Quarry, the most likely receptors are individuals entering the area on an occasional basis to evaluate wildlife to meet the needs of natural resources management (e.g., wildlife biologist) or to check the status of the area for security or safety reasons, or maintenance workers performing periodic mowing, landfill cap repair, and periodic post-closure groundwater sampling. None of these activities involve routine exposure at Ramsdell Quarry; rather, they are occasional activities. Also, none of these activities involve contact with wetlands when they are present (i.e., maintenance workers are not expected to work in areas that are under water).

Future sampling of environmental media (e.g., surface water or groundwater) may occur at Ramsdell Quarry; however, exposure by sampling personnel is not evaluated in the risk assessment because workers engaged in environmental sampling are expected to wear proper personal protective equipment, including gloves, and follow health and safety protocols (e.g., no eating or smoking) to minimize/prevent incidental exposure.

Ramsdell Quarry is considered a seasonal wetland and is not a fishery because of the fluctuating water level. Trespassers are possible, although unlikely at RVAAP; however, Ramsdell Quarry is restricted access due to MEC concerns and trespassers are not expected at this site. Hunting is not allowed within the AOC.

Based on this information, the Security Guard/Maintenance Worker scenario outlined in Table 5 of the FWHHRAM (USACE 2004b) is protective of potential receptors at RQL. This scenario assumes a Security Guard/Maintenance Worker patrols Ramsdell Quarry every day for 1 hr. Although a security guard is not currently exposed to contaminated media at Ramsdell Quarry on a daily basis, the potential exposure of this receptor is considered protective of receptors with more irregular exposure (e.g., a wildlife ecologist who spends several days at the site once every few years, security personnel who may periodically evaluate the site, or workers engaged in periodic maintenance).

The Security Guard/Maintenance Worker is assumed to be exposed to surface soil (0 to 1 ft bgs) only. Subsurface soil is not evaluated because (1) shallow bedrock precludes the collection of subsurface samples and (2) the Security Guard/Maintenance Worker is not exposed to this medium, per Table 5 of the FWHHRAM. This receptor is not involved in recreational or training activities that would result in exposure to surface water or sediment.

Exposures to contaminants in surface soil at RQL are evaluated for a Security Guard/Maintenance Worker for soil ingestion, dermal contact with soil, and inhalation of soil particles and VOCs.

In addition to the representative receptor described above, the other four receptors described in the FWHHRAM [National Guard Trainee, National Guard Dust/Fire Control Worker, Hunter/Fisher, and Resident Subsistence Farmer (adult and child)] are evaluated to provide additional information for evaluation in the FS (e.g., to establish the need for institutional controls). These additional receptors are not anticipated at RQL due to physical constraints and intended future land use by OHARNG. The National Guard Trainee is not anticipated due to physical constraints (e.g., wetlands, MEC, and landfill) and the OHARNG Land Use Plan, as summarized in the FWHHRAM (USACE 2004b), which does not include training in this area. The National Guard Dust/Fire Control Worker is not anticipated for the same reasons as the Trainee, plus RQL is only a seasonal wetland and is sometimes dry year-round. The Hunter/Fisher is not anticipated due to MEC, OHARNG prohibition of hunting in this area, lack of a fishery (due to shallow, ephemeral water), and poor habitat for waterfowl. The Resident Subsistence Farmer (adult and child) provides a baseline for evaluating this site with respect to unrestricted release.

6.3.3 Exposure Point Concentrations

6.3.3.1 EPCs in groundwater, surface soil, sediment, and surface water

This HHRA for RQL evaluates the reasonable maximum exposure (RME). The RME is an estimate of the highest exposure reasonably expected to occur at the site. Because of the uncertainty associated with any estimate of exposure concentration, the UCL_{95} for either a normal or lognormal distribution is the recommended statistic for evaluating the RME. In cases where the UCL_{95} exceeds the MDC, the maximum concentration is used as an estimate of the RME.

EPCs are calculated using equations from EPA guidance*, Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA 1992b). The data are tested using the Shapiro-Wilk test to determine distribution, normal or lognormal, of the concentrations. This guidance notes that environmental data are often lognormally distributed but does not give specific guidance for data sets with unknown distributions.

For RQL, the UCL_{95} on the mean is calculated using the normal distribution equation (see Equation 6-1) when the concentrations are normally distributed, when concentrations are not judged to be normally or lognormally distributed, when the data set contains fewer than five detections, or when the frequency of detection is less than 50%. For these situations, the UCL_{95} on the mean is calculated using the following equation:

$$UCL_{95}(normal) = \bar{x}_n + \frac{(t)(s_x)}{\sqrt{n}}, \qquad \textbf{(6-1)}$$

where

$\bar{x}_n$ = mean of the untransformed data,
t = student-t statistic,
s_x = standard deviation of the untransformed data,
n = number of sample results available.

EPA guidance *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (EPA 2002b) provides several methods for calculating the UCL_{95} for data sets that are neither normally nor log-normally distributed. All of the methods in this guidance are based on the assumption of random sampling. Sampling at Ramsdell Quarry was biased toward areas with the greatest potential for contamination. The reason for defaulting to the t-distribution (i.e., assumption of normality) when the distribution cannot be determined is that this method is simple and robust; even when the assumption that the underlying distribution is normal is violated, the estimate of the UCL_{95} is reasonably close to the true value.

For lognormally distributed concentrations, the UCL_{95} on the mean is calculated using the following equation:

$$UCL_{95}(lognormal) = e^{\left(\overline{x_l} + 0.5(s_l^2) + \frac{(S_l)(H)}{\sqrt{n-1}}\right)}, \quad \textbf{(6-2)}$$

where

e = constant (base of the natural log, equal to 2.718),
$\overline{x}_l$ = mean of the transformed data [l = log (x)],
s_l = standard deviation of the transformed data,
H = H-statistic,
n = number of sample results available.

EPA guidance (EPA 2002b) notes that use of the H statistic may result in overestimating the true UCL_{95} on the mean if the data are not lognormal. Even small deviations from lognormality can greatly influence the results using the H-statistic, yielding upper bounds that are much too large (Singh et al., 1997).

EPCs for groundwater, surface soil, sediment, and surface water are provided in Appendix L, Tables L-1 through L-4.

6.3.3.2 EPCs in foodstuffs for the Resident Subsistence Farmer

Direct sampling results are not available for the evaluation of ingestion of foodstuffs (i.e., beef, milk, venison, and vegetables). Exposure concentrations were modeled for these media using the equations presented below. The starting concentration of COPCs in soil is equal to the EPC calculated for direct exposure pathways, as described in Section 6.3.3.1. Other parameter values are provided in Table 6-6.

Chemical Concentration in Beef

Concentrations in beef cattle are calculated from the concentration in the cattle's food sources due to soil contamination. The contaminant levels in pastures are estimated by the equation:

$$C_p = C_s \times (R_{upp} + R_{es}), \quad \textbf{(6-3)}$$

where
C_p = concentration of contaminant in pasture (mg/kg, calculated),
C_s = concentration of contaminant in soil (mg/kg),
R_{upp} = multiplier for dry root uptake for pasture (unitless),
R_{es} = resuspension multiplier (unitless).

The multiplier for dry root uptake for pasture, R_{upp}, is chemical-specific and is estimated as:

$$R_{upp} = Bv_{dry}, \quad \textbf{(6-4)}$$

where
R_{upp} = multiplier for dry root uptake for pasture (unitless),

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a]

		Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
Exposure Pathway and Parameter	Units	Security Guard/ Maintenance Worker[b]	Dust/Fire Control	Trainee	Hunter/ Fisher[c]	Adult	Child
Surface Soil[e]							
Incidental Ingestion							
Soil ingestion rate	kg/d	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Exposure time	h/d	1	4	24	6[e]	24	24
Exposure frequency	d/year	250	15	39	2[e]	350	350
Exposure duration	years	25	25	25	30	30	6
Body weight	kg	70	70	70	70	70	15
Carcinogen averaging time	d	25,550	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	9,125	9,125	9,125	10,950	10,950	2,190
Fraction ingested	Unitless	1	1	1	1	1	1
Conversion factor	d/h	0.042	0.042	0.042	0.042	0.042	0.042
Dermal Contact							
Skin area	m^2/event	0.33	0.33	0.33	0.52[f]	0.57	0.22
Adherence factor	mg/cm^2	0.7	0.3	0.3	0.3	0.4	0.2
Absorption fraction	Unitless	Chemical Specific – See Table L-5					
Exposure frequency	events/year	250	15	39	2[e]	350	350
Exposure duration	years	25	25	25	30	30	6
Body weight	kg	70	70	70	70	70	15
Carcinogen averaging time	d	25,550	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	9,125	9,125	9,125	10,950	10,950	2,190
Conversion factor	(kg-cm^2)/(mg-m^2)	0.01	0.01	0.01	0.01	0.01	0.01
Inhalation of VOCs and Dust							
Inhalation rate	m^3/d	20	44.4	44.4	20	20	10
Exposure time	h/d	1	4	24	6[e]	24	24
Exposure frequency	d/year	250	15	39	2[e]	350	350
Exposure duration	years	25	25	25	30	30	6
Body weight	kg	70	70	70	70	70	15
Carcinogen averaging time	d	25,550	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	9,125	9,125	9,125	10,950	10,950	2,190
Conversion factor	d/h	0.042	0.042	0.042	0.042	0.042	0.042

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

		Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker[b]**	**Dust/Fire Control**	**Trainee**	**Hunter/ Fisher[c]**	**Adult**	**Child**
Subsurface Soil							
Incidental Ingestion							
Soil ingestion rate	kg/d	NA	NA	NA	NA	0.0001	0.0002
Exposure time	h/d	NA	NA	NA	NA	24	24
Exposure frequency	d/year	NA	NA	NA	NA	350	350
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	d	NA	NA	NA	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	NA	NA	10,950	2,190
Fraction ingested	Unitless	NA	NA	NA	NA	1	1
Conversion factor	d/h	NA	NA	NA	NA	0.042	0.042
Dermal Contact							
Skin area	m^2/event	NA	NA	NA	NA	0.57	0.22
Adherence factor	mg/cm^2	NA	NA	NA	NA	0.4	0.2
Absorption fraction	Unitless	NA	NA	NA	NA	Chem. Spec. See Table L-5	
Exposure frequency	events/year	NA	NA	NA	NA	350	350
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	d	NA	NA	NA	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	NA	NA	10,950	2,190
Conversion factor	(kg-cm^2)/(mg-m^2)	NA	NA	NA	NA	0.01	0.01
Inhalation of VOCs and Dust							
Inhalation rate	m^3/d	NA	NA	NA	NA	20	10
Exposure time	h/d	NA	NA	NA	NA	24	24
Exposure frequency	d/year	NA	NA	NA	NA	350	350
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	d	NA	NA	NA	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	NA	NA	10,950	2,190

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

		Potential Receptor					
		National Guard Personnel				**Resident Subsistence Farmer**	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker[b]**	**Dust/Fire Control**	**Trainee**	**Hunter/ Fisher[c]**	**Adult**	**Child**
Conversion factor	d/h	NA	NA	NA	NA	0.042	0.042
Sediment							
Incidental Ingestion							
Soil ingestion rate	kg/d	NA	0.0001	0.0001	0.0001	0.0001	0.0002
Exposure time	h/d	NA	4	24	6[e]	24	24
Exposure frequency	d/year	NA	15	39	2[e]	350	350
Exposure duration	years	NA	25	25	30	30	6
Body weight	kg	NA	70	70	70	70	15
Carcinogen averaging time	d	NA	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	9,125	9,125	10,950	10,950	2,190
Fraction ingested	Unitless	NA	1	1	1	1	1
Conversion factor	d/h	NA	0.042	0.042	0.042	0.042	0.042
Dermal Contact							
Skin area	m^2/event	NA	0.33	0.33	0.52[f]	0.57	0.22
Adherence factor	mg/cm^2	NA	0.3	0.3	0.3	0.4	0.2
Absorption fraction	Unitless	NA	Chemical Specific – See Table L-5				
Exposure frequency	events/year	NA	15	39	2[e]	350	350
Exposure duration	years	NA	25	25	30	30	6
Body weight	kg	NA	70	70	70	70	15
Carcinogen averaging time	d	NA	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	9,125	9,125	10,950	10,950	2,190
Conversion factor	(kg-cm^2)/(mg-m^2)	NA	0.01	0.01	0.01	0.01	0.01
Inhalation of VOCs and Dust							
Inhalation rate	m^3/d	NA	44.4	44.4	20[b]	20	10
Exposure time	h/d	NA	4	24	6[e]	24	24
Exposure frequency	d/year	NA	15	39	2[e]	350	350
Exposure duration	years	NA	25	25	30	30	6
Body weight	kg	NA	70	70	70	70	15
Carcinogen averaging time	d	NA	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	9,125	9,125	10,950	10,950	2,190
Conversion factor	d/h	NA	0.042	0.042	0.042	0.042	0.042

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

Exposure Pathway and Parameter	Units	Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
		Security Guard/ Maintenance Worker[b]	Dust/Fire Control	Trainee	Hunter/ Fisher[c]	Adult	Child
Surface Water							
Incidental Ingestion							
Incidental water ingestion rate	L/d	NA	0.1	0.1	0.05[g]	0.1	0.1
Exposure frequency	d/year	NA	15	39	2[e]	350	350
Exposure duration	years	NA	25	25	30	30	6
Body weight	kg	NA	70	70	70	70	15
Carcinogen averaging time	d	NA	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	9,125	9,125	10,950	10,950	2,190
Dermal Contact							
Skin area	m^2	NA	0.33	0.33	0.52[f]	0.57	0.22
Exposure time	h/d	NA	4	24	6[e]	2.5	2.5
Exposure frequency	d/year	NA	15	39	2[e]	350	350
Exposure duration	years	NA	25	25	30	30	6
Body weight	kg	NA	70	70	70	70	15
Carcinogen averaging time	d	NA	25,550	25,550	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	9,125	9,125	10,950	10,950	2,190
Conversion factor	$(m/cm)(L/m^3)$	NA	10	10	10	10	10
Groundwater							
Drinking Water Ingestion							
Drinking water ingestion rate	L/d	NA	NA	2	NA	2	1.5
Exposure frequency	d/year	NA	NA	39	NA	350	350
Exposure duration	years	NA	NA	25	NA	30	6
Body weight	kg	NA	NA	70	NA	70	15
Carcinogen averaging time	d	NA	NA	25,550	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	9,125	NA	10,950	2,190
Dermal Contact While Showering							
Skin area	m^2	NA	NA	1.94	NA	1.94	0.866
Exposure time	h/d	NA	NA	0.25	NA	0.25	0.25
Exposure frequency	d/year	NA	NA	39	NA	350	350
Exposure duration	years	NA	NA	25	NA	30	6
Body weight	kg	NA	NA	70	NA	70	15

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

		Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker[b]**	**Dust/Fire Control**	**Trainee**	**Hunter/ Fisher[c]**	**Adult**	**Child**
Carcinogen averaging time	d	NA	NA	25,550	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	9,125	NA	10,950	2,190
Conversion factor	(m/cm)(L/m^3)	NA	NA	10	NA	10	10
Inhalation of VOCs During Household Water Use							
Inhalation rate	m^3/d	NA	NA	20	NA	20	10
Exposure frequency	d/year	NA	NA	39	NA	350	350
Exposure duration	years	NA	NA	25	NA	30	6
Body weight	kg	NA	NA	70	NA	70	15
Carcinogen averaging time	d	NA	NA	25550	NA	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	9125	NA	10,950	2,190
Volatilization factor	L/m^3	NA	NA	0.5	NA	0.5b	0.5b
Foodstuffs							
Ingestion of Fish							
	kg/d	NA	NA	NA	0.054	0.054	0.054
Fraction ingested	Unitless	NA	NA	NA	1	1	1
Exposure frequency	d/year	NA	NA	NA	365	365	365
Exposure duration	years	NA	NA	NA	30	30	6
Body weight	kg	NA	NA	NA	70	70	15
Carcinogen averaging time	d	NA	NA	NA	25,550	25,550	25,550
Non-carcinogen averaging time	d	NA	NA	NA	10,950	10,950	2,190
Ingestion of Waterfowl							
Waterfowl ingestion rate	kg/d	NA	NA	NA	0.0132	NA	NA
Fraction ingested	Unitless	NA	NA	NA	1	NA	NA
Exposure frequency	d/year	NA	NA	NA	365	NA	NA
Exposure duration	years	NA	NA	NA	30	NA	NA
Body weight	kg	NA	NA	NA	70	NA	NA
Carcinogen averaging time	d	NA	NA	NA	25,550	NA	NA
Non-carcinogen averaging time	d	NA	NA	NA	10,950	NA	NA
Ingestion of Venison							
Conversion factor	unitless	NA	NA	NA	NA	1.25	1.25
Browse ingestion rate	kg dry weight/day	NA	NA	NA	NA	0.87	0.87

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

		Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
Exposure Pathway and Parameter	Units	Security Guard/ Maintenance Worker[b]	Dust/Fire Control	Trainee	Hunter/ Fisher[c]	Adult	Child
Fraction browse ingested from site	unitless	NA	NA	NA	NA	0.032[h]	0.032[h]
Fat ratio (venison to beef)	unitless	NA	NA	NA	NA	0.2	0.2
Venison ingestion rate	kg/day	NA	NA	NA	NA	0.03	0.03
Fraction ingested	unitless	NA	NA	NA	NA	1	1
Exposure frequency	days/year	NA	NA	NA	NA	365	365
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	days	NA	NA	NA	NA	25,550	25,550
Noncarcinogen averaging time	days	NA	NA	NA	NA	10,950	2,190
Ingestion of Beef, Pork							
Resuspension multiplier	unitless	NA	NA	NA	NA	0.25	0.25
Quantity of pasture ingested	kg dry weight/day	NA	NA	NA	NA	7.2	7.2
Fraction of year cow is on-site	unitless	NA	NA	NA	NA	1	1
Fraction of cow's food from on-site	unitless	NA	NA	NA	NA	0.9	0.9
Quantity of soil ingested by cow	kg/day	NA	NA	NA	NA	1	1
Beef ingestion rate	kg/day	NA	NA	NA	NA	0.075	0.075
Fraction ingested	unitless	NA	NA	NA	NA	1	1
Exposure frequency	days/year	NA	NA	NA	NA	365	365
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	days	NA	NA	NA	NA	25,550	25,550
Noncarcinogen averaging time	days	NA	NA	NA	NA	10,950	2,190
Ingestion of Milk Products							
Resuspension multiplier	unitless	NA	NA	NA	NA	0.25	0.25
Quantity of pasture ingested	kg dry weight/day	NA	NA	NA	NA	16.1	16.1
Fraction of year cow is on-site	unitless	NA	NA	NA	NA	1	1
Fraction of cow's food from on-site	unitless	NA	NA	NA	NA	0.6	0.6
Quantity of soil ingested by cow	kg/day	NA	NA	NA	NA	1	1
Milk ingestion rate	kg/day	NA	NA	NA	NA	0.305	0.509
Fraction ingested	unitless	NA	NA	NA	NA	1	1
Exposure frequency	days/year	NA	NA	NA	NA	365	365

Table 6-6. Parameters Used to Quantify Exposures for Each Medium and Receptor at Ramsdell Quarry[a] (continued)

		Potential Receptor					
		National Guard Personnel				**Resident Subsistence Farmer**	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker[b]**	**Dust/Fire Control**	**Trainee**	**Hunter/ Fisher[c]**	**Adult**	**Child**
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	days	NA	NA	NA	NA	25,550	25,550
Noncarcinogen averaging time	days	NA	NA	NA	NA	10,950	2,190
Ingestion of Vegetables							
Resuspension multiplier	unitless	NA	NA	NA	NA	0.26	0.26
Vegetable ingestion rate	kg/day	NA	NA	NA	NA	0.2	0.2
Fraction ingested	unitless	NA	NA	NA	NA	0.4	0.4
Exposure frequency	days/year	NA	NA	NA	NA	365	365
Exposure duration	years	NA	NA	NA	NA	30	6
Body weight	kg	NA	NA	NA	NA	70	15
Carcinogen averaging time	days	NA	NA	NA	NA	25,550	25,550
Noncarcinogen averaging time	days	NA	NA	NA	NA	10,950	2,190

[a] All parameters are from Table 5 of *RVAAP's Facility Wide Human Health Risk Assessor Manual* (FWHHRAM) (USACE, 2004b), unless otherwise noted.

[b] Security Guard/Maintenance Worker is the representative receptor at the Ramsdell Quarry Landfill (RQL).

[c] Ramsdell Quarry is not a fishery because of the fluctuating water level (it is a seasonal wetland); therefore, the hunter/fisher receptor is evaluated as a hunter only.

[d] Surface soil is defined as 0 to 1 ft bgs (shallow surface soil) for all receptors except the National Guard Trainee. Surface soil is defined as 0 to 4 ft bgs (deep surface soil) for the National Guard Trainee; however, at RQL no samples are available below 1 ft due to the presence of shallow bedrock.

[e] Per the FWHHRAM, the hunter is assumed to be on-site 6 hrs/day for 2 days/year.

[f] Per footnote d of Table 5 in FWHHRAM. Value in Table 5 (0.57) is incorrect and is inconsistent with skin area listed in Table 5 for this receptor for other media.

[g] Per footnote b of Table 5 in FWHHRAM. Hunter/Fisher is assumed to ingest 0.05 L/day due to splashing while setting traps or wading. Value in Table 5 (0.1) is incorrect.

[h] Fraction brows calculated as RQL exposure area (14 acres or 5.67 ha) divided by deer home range (175 ha).

NA = Not applicable for this scenario.

VOC = Volatile organic compound.

Bv_{dry} = soil-to-plant uptake, dry weight (kg/kg, chemical-specific, or $38 \times K_{ow}^{-0.58}$),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific).

The concentration of contaminants in beef cattle from ingestion of contaminated pasture and soil is estimated using the following equation:

$$C_b = BTF_{beef} \times [(C_p \times Q_{pb} \times f_{pb} \times f_{sb}) + (C_s \times Q_{sb} \times f_{pb})], \qquad \textbf{(6-5)}$$

where
C_b = concentration of contaminant in beef (mg/kg dry weight),
BTF_{beef} = beef transfer coefficient (day/kg),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific),
C_p = concentration of contaminant in pasture (mg/kg, calculated),
Q_{pb} = quantity of pasture ingested by beef cattle (kg/day),
f_{pb} = fraction of year beef cattle is on-site (kg/day),
f_{sb} = fraction of beef cattle's food that is from the site (kg/day),
C_s = concentration of contaminant in soil (mg/kg),
Q_{sb} = quantity of soil ingested by beef cattle (kg/day).

The BTF_{beef} for metals is taken from available literature. The BTF_{beef} for SVOCs is calculated as $2.5 \times 10^{-8} \times K_{ow}$. A BTF_{beef} is not estimated for VOCs because these chemicals are expected to volatilize rapidly from soils and plants and, thus, are insignificant in food chain pathways.

Chemical concentration in milk

Milk concentrations from dairy cattle are calculated from the concentration in the cattle's food sources due to soil contamination. The contaminant levels in pastures are estimated in the same fashion as for beef cattle.

The concentration of contaminants in dairy cattle's milk from ingestion of contaminated pasture and soil is estimated using the following equation:

$$C_m = BTF_{milk} \times [(C_p \times Q_{pd} \times f_{pd} \times f_{sd}) + (C_s \times Q_{sd} \times f_{pd})], \qquad \textbf{(6-6)}$$

where
C_m = concentration of contaminant in milk (mg/kg),
BTF_{milk} = milk transfer coefficient (day/kg),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific),
C_p = concentration of contaminant in pasture (mg/kg, calculated),
Q_{pd} = quantity of pasture ingested by dairy cattle (kg/day),
f_{pd} = fraction of year dairy cattle is on-site (kg/day),
f_{sd} = fraction of dairy cattle's food that is from the site (kg/day),
C_s = concentration of contaminant in soil (mg/kg),
Q_{sd} = quantity of soil ingested by dairy cattle (kg/day).

The BTF_{milk} for metals is taken from available literature. The BTF_{milk} for SVOCs is calculated as $7.5 \times 10^{-9} \times K_{ow}$. A BTF_{milk} is not estimated for VOCs because these chemicals are expected to volatilize rapidly from soils and plants and, thus, are insignificant in food chain pathways.

Chemical concentration in venison

Concentrations in venison are estimated by calculating the concentration in venison food sources due to soil contamination. The contaminant levels in forage are estimated by the following:

$$C_{p} = (CF)(C_s)(B_p) \qquad \textbf{(6-7)}$$

where
C_p = concentration of contaminant in forage (mg/kg dry weight),
CF = conversion factor to adjust for soil containing 20% moisture (1.25 unitless),
C_s = concentration of contaminant in soil (mg/kg),
B_p = soil-to-forage biotransfer factor (mg chemical per kg of dry plant/mg of chemical per kg or dry soil)(chemical-specific).

The B_p for metals is taken from the available literature. The B_p for SVOCs is calculated using the following formula:

$$\log B_p = 1.588 - 0.578 \log K_{ow} \qquad \textbf{(6-8)}$$

where
$\log B_p$ = soil-to-forage biotransfer factor (mg chemical per kg of dry plant/mg of chemical per kg or dry soil)(chemical-specific),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific).

A B_p is not estimated for VOCs because these chemicals are expected to volatilize rapidly from soils and plants and, thus, are insignificant in food chain pathways.

The concentration of contaminants in venison from ingestion of contaminated forage is estimated using the following equation:

$$C_v = (Q_p)(C_p)(FI_e)(B_v) \qquad \textbf{(6-9)}$$

where
C_v = contaminant concentration in venison (mg/kg),
Q_p = browse ingestion rate (0.87 kg dry weight/day),
C_p = contaminant concentration in browse (mg/kg dry weight),
FI_e = fraction browse ingested from the contaminated site (site area/home range),
B_v = biotransfer factor for venison (days/kg).

The B_v for beef is used for deer due to a lack of available literature values for deer. Both of these animals are ruminants; therefore, the uptake and bioaccumulation of contaminants is likely to be similar. The meat of deer contains less fat than commercial beef—14.4 % fat for beef, compared to 2.9% for venison. Organic chemicals have a greater affinity to fat and, thus, would not accumulate as much in venison. Therefore, the beef biotransfer factors for organics are adjusted by 2.9/14.4 (0.20) to reflect this lower accumulation rate.

The fraction browse ingested from the contaminated site is exposure unit-specific. Fraction browse for the 14 acre RQL AOC is 0.032 (5.67 ha/175 ha) based on a 175-hactare home range for deer.

The B_v values for metals are taken from the published literature. The B_v values for organics are calculated as follows:

$$B_v = R_f \times 10^{-7.6 + \log K_{ow}}, \qquad \textbf{(6-10)}$$

where

B_v = biotransfer factor for venison (days/kg),
R_f = ratio of the fat content in venison to the fat content of beef (0.20),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific).

Chemical concentration in homegrown vegetables

The chemical concentration in homegrown vegetables is estimated with the equation:

$$C_{veg} = C_s \times (Bv_{wet} + MLF), \qquad \textbf{(6-11)}$$

where
C_s = concentration of contaminant in soil (mg/kg),
Bv_{wet} = soil-to-plant uptake, wet weight (kg/kg, chemical-specific, or $7.7 \times K_{ow}^{-0.58}$),
K_{ow} = octanol-water partitioning coefficient (unitless, chemical-specific),
MLF = plant mass loading factor (unitless, 0.26 for vegetables).

A C_{veg} is not estimated for VOCs because these chemicals are expected to volatilize rapidly from soils and plants and, thus, are insignificant in food chain pathways.

6.3.3.3 Exposure point concentrations in waterfowl for Hunter

The determination of EPCs in waterfowl is described in detail in Appendix L, Section L3. EPCs for waterfowl are presented in Table L-27. These EPCs are calculated assuming waterfowl are exposed continuously to contaminants at RQL only. This assumption is conservative for two reasons:

- Waterfowl are migratory and spend only a portion of their time at RVAAP.
- The home range of waterfowl at RVAAP is larger than RQL; therefore, while at RVAAP, waterfowl spend only a portion of their time at RQL.

Ramsdell Quarry is a seasonal wetland; therefore, the hunter/fisher is assumed to hunt only (no fishing). Because Ramsdell Quarry is not a fishery, no fish tissue EPCs are calculated.

6.3.4 Exposure Parameters and Calculations for Estimating Intakes

Standard intake equations from EPA guidance (EPA 1989b) for ingestion, dermal contact, and inhalation of chemicals in water, soil/sediment, and food (shown above) are used, along with the exposure parameters shown in Table 6-6. Exposure parameters and intake equations are from the FWHHRAM (USACE 2004b).

Incidental ingestion of soil is estimated using Equation 6-12:

$$\text{Chemical Intake (mg/kg-day)} = \frac{C_S \times IR_S \times EF \times ED \times FI \times ET \times CF}{BW \times AT}, \qquad \textbf{(6-12)}$$

where

C_s = chemical concentration in soil (mg/kg),
IR_s = ingestion rate (kg/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
FI = fraction ingested (value of 1, unitless),
ET = exposure time (hr/day),
CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

The dermally absorbed dose (DAD) from chemicals in soil is calculated using Equation 6-13.

$$\frac{C_S \times \mathrm{CF} \times \mathrm{SA} \times \mathrm{AF} \times \mathrm{ABS} \times \mathrm{EF} \times \mathrm{ED}}{\text{Chemical DAD (mg/kg-day)}} = \mathrm{BW} \times \mathrm{AT}, \tag{6-13}$$

where

C_s = chemical concentration in soil (mg/kg),
CF = conversion factor [$(10^{-6}$ kg/mg$) \times (10^{4}$ cm^2/m$^2)$],
SA = skin surface area exposed to soil (m^2/event),
AF = soil to skin adherence factor (mg/cm^2),
ABS = chemical-specific absorption factor (unitless; see Table L-5),
EF = exposure frequency (events/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

Inhalation of soil is calculated using Equation 6-14:

$$\frac{C_S \times \mathrm{IR}_a \times \mathrm{EF} \times \mathrm{ED} \times \left(VF^{-1} + PEF^{-1}\right) \times \mathrm{ET} \times CF}{\text{Chemical Intake (mg/kg-day)}} = BW \times AT, \tag{6-14}$$

where

C_s = chemical concentration in soil (mg/kg),
IR_a = inhalation rate (m^3/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
VF = chemical-specific volatilization factor (m^3/kg; see Table L-5),
PEF = particulate emission factor (m^3/kg),
ET = exposure time (hr/day),
CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

Per the FWHHRAM (USACE 2004b), the general PEF value used for all receptors except the National Guard Trainee is the default value for Cleveland, Ohio (9.24E+08 m^3/kg) from the EPA Soil Screening Guidance on-line at http://risk.lsd.ornl.gov/epa/ssl1.htm. A smaller PEF value (1.67×10^6) is used for the National Guard Trainee scenario because the activities of this receptor are assumed to generate more dust. This PEF value was calculated from a dust-loading factor (DLF) of 600 μg/m^3 (DOE 1983) as:

$$PEF = 1/(DLF \times \text{Conversion Factor}) = 1/(600\ \mu g/m^3 \times 1E\text{-}09\ kg/\mu g) = 1.67E{+}06\ m^3/kg.$$

6.3.4.1 Exposure equations for other receptors

Incidental ingestion, dermal contact, and inhalation of COPCs in sediment are estimated using the same equations presented above for surface soil exposures.

Incidental ingestion of surface water and drinking water ingestion from groundwater are estimated using Equation 6-15:

$$\text{Chemical Intake (mg/kg-day)} = \frac{C_W \times IR_W \times EF \times ED}{BW \times AT}, \tag{6-15}$$

where

C_w = chemical concentration in surface water (mg/L),
IR_w = ingestion rate (L/day),
EF = exposure frequency (day/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

The DAD from dermal contact with chemicals in surface water and groundwater is calculated by using Equation 6-16:

$$\text{Chemical DAD (mg/kg-day)} = \frac{C_W \times CF \times PC \times SA \times ET \times EF \times ED}{BW \times AT}, \tag{6-16}$$

where

C_w = chemical concentration in water (mg/L),
CF = conversion factor [(m/100 cm) × (1,000 L/m^3)],
PC = chemical-specific permeability constant (cm/h; see Table L-5),
SA = skin surface area exposed to surface water (m^2),
ET = exposure time (h/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

Inhalation of VOCs from groundwater was estimated by using Equation 6-17:

$$\text{Chemical Intake (mg/kg-day)} = \frac{C_w \times IR_w \times K \times EF \times ED \times ET \times CF}{BW \times AT}, \tag{6-17}$$

where
C_w = chemical concentration in water (mg/L),
IR_w = inhalation rate (m^3/day),

K = volatilization factor ($0.0005 \times 1{,}000\ \mathrm{L/m^3}$),
EF = exposure frequency (days/year),
ED = exposure duration (years),
ET = exposure time adjustment (hr/day),
CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

Inhalation of VOCs from surface water is not quantified because the surface water at RQL is intermittent and only two VOCs (methylene chloride and tetrachloroethene) were identified as COPCs in a single surface water sample.

6.3.4.2 Ingestion of food pathway

Ingestion of food (beef, milk, vegetables, venison, and waterfowl) is estimated using Equation 6-18:

$$Chemical\ Intake\ (mg/kg\text{-}day) = \frac{C_F \times IR_F \times EF \times ED \times FI}{BW \times AT}, \qquad \textbf{(6-18)}$$

where

C_F = chemical-specific concentration in food (mg/kg),
IR_F = ingestion rate of food product (kg/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
FI = fraction ingested (value of 1, unitless),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

6.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to evaluate the potential for COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the intake or dose of a COPC and the likelihood or severity of adverse health effects as a result of that exposure. Toxic effects have been evaluated extensively by EPA. This chapter provides the results of the EPA evaluation of the chemicals identified as COPCs at RQL.

6.4.1 Toxicity Information and U. S. Environmental Protection Agency Guidance for Non-carcinogens

Non-carcinogenic effects are evaluated by comparing an exposure or intake/dose with a reference dose (RfD) or reference concentration (RfC). The RfD and RfCs are determined using available dose-response data for individual chemicals. Scientists determine the exposure concentration or intake/dose below which no adverse effects are seen and add a safety factor (from 10 to 1,000) to determine the RfD or RfC. RfDs and RfCs are identified by scientific committees supported by EPA. The RfDs available for the COPCs present in the surface soil at RQL are listed in Table L-6 (EPA 1997c, 2005). In this HHRA, RfCs, measured in milligrams per cubic meter, were converted to RfDs expressed in units of milligrams per kilogram body weight per day by using the default adult inhalation rate and body weight [i.e., (RfC × 20 $\mathrm{m^3}$/day)/70 kg = RfD] (EPA 1989b).

Chronic RfDs are developed for protection from long-term exposure to a chemical (from 7 years to a lifetime); subchronic RfDs are used to evaluate short-term exposure (from 2 weeks to 7 years) (EPA 1989b). Since potential receptors at RQL are not considered to have short-term exposure, only chronic RfDs are used in this HHRA.

Toxic effects are diverse and measured in various target body organs (e.g., they range from eye irritation to kidney or liver damage). EPA is currently reviewing methods for accounting for the difference in severity of effects; however, existing RfDs do not address this issue.

6.4.2 Toxicity Information and U. S. Environmental Protection Agency Guidance for Carcinogens

For carcinogens, risks are estimated as the probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as excess or incremental cancer risk, which is cancer occurrence in addition to normally expected rates of cancer development. Excess cancer risk is estimated using a cancer slope factor (CSF). The CSF is defined as a plausible upper-bound estimate of the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime (EPA 1989b).

EPA expresses inhalation cancer potency as the unit risk based on the chemical concentration in air [i.e., risk per microgram (μg) of chemical per cubic meter (m^3) of ambient air]. These unit risks were converted to CSFs expressed in units of risk per mg of chemical per kg body weight per day by using the default adult inhalation rate and body weight [i.e., (Unit Risk × 70 kg × 1,000 μg/mg)/20 m^3/day].

CSFs used in the evaluation of risk from carcinogenic COPCs are listed in Table L-7 (EPA 1997c, 2005).

6.4.3 Estimated Toxicity Values for Dermal Exposure

Oral and inhalation RfDs and CSFs are currently available. Dermal RfDs and CSFs are estimated from oral toxicity values using chemical-specific gastrointestinal absorption factors (GAFs) to calculate total absorbed dose. This conversion is necessary because most oral RfDs and CSFs are expressed as the amount of chemical administered per time and body weight; however, dermal exposure is expressed as an absorbed dose. Dermal toxicity factors are calculated from oral toxicity factors as shown below (EPA 2002b):

$$RfD_{dermal} = RfD_{oral} \times GAF \qquad \textbf{(6-19)}$$

$$CSF_{dermal} = CSF_{oral}/GAF \qquad \textbf{(6-20)}$$

Per FWHHRAM, dermal CSFs and RfDs are estimated from the oral toxicity values using chemical-specific GAFs to calculate the total absorbed dose only for chemicals with GAF values < 0.5. Chemical-specific GAF values available from EPA (2002a) are used whenever possible. Not all COPCs have specific GAF values. When quantitative data are insufficient, a default GAF is used. A default value of 1.0 for organic and inorganic chemicals is used (EPA 2002a). The GAF and resulting dermal toxicity values used in this HHRA are listed in Tables L-6 and L-7.

6.4.4 Assumptions Used in the Toxicity Assessment

Assumptions made in assigning toxicity values for COPCs at RQL are:

- Total chromium is evaluated using the toxicity values for hexavalent chromium. This is the form of chromium with the most conservative toxicity values.

- Thallium, as a metal, is evaluated using the toxicity values for thallium carbonate. This is the form of thallium with the most conservative toxicity values.

- Toxicity equivalency factors (TEFs) are applied to carcinogenic polycyclic aromatic hydrocarbons (cPAHs). The following TEFs are used to convert the cPAHs identified as COPCs at RQL to an equivalent concentration of benzo(*a*)pyrene.

cPAH	TEF
Benzo(*a*)pyrene	1
Benz(*a*)anthracene	0.1
Benzo(*b*)fluoranthene	0.1
Benzo(*k*)fluoranthene	0.01
Chrysene	0.001
Dibenzo(*a,h*)anthracene	1
Indeno(1,2,3-*cd*)pyrene	0.1

6.4.5 Chemicals without U. S. Environmental Protection Agency Toxicity Values

No RfDs or CSFs are available for some detected chemicals at RQL because the non-carcinogenic and/or carcinogenic effects of these chemicals have not yet been determined. Although these chemicals may contribute to health effects from exposure to contaminated media at RQL, their effects cannot be quantified at the present time. COPCs without RfDs and CSFs are sulfate; 2-amino-4,6-DNT; 4-amino-2,6-DNT; nitroglycerin; nitrocellulose; acenaphthylene; benzo(*g,h,i*)perylene; and phenanthrene.

Previously withdrawn or provisional toxicity values are used for one COPC at RQL: benzo(*a*)pyrene uses a provisional inhalation CSF. Without this provisional value, the inhalation pathway could not be quantitatively evaluated for this chemical.

No RfDs or CSFs are available for lead. EPA (1999b) recommends the use of the Interim Adult Lead Methodology (ALM) to support its goal of limiting risk of elevated fetal blood lead (PbB) concentrations due to lead exposures to women of child-bearing age. This model is used to estimate the probability that the fetal PbB level will exceed 10 µg/dL as a result of maternal exposure. Complete documentation of the model is available at http://www.epa.gov/superfund/programs/lead/products/adultpb.pdf (EPA 2003b). The model-supplied default values were used for all parameters, with the exception of the site-specific media concentration and exposure frequency. Input parameters and results of this model are provided in Appendix L, Tables L-8 through L-10. The ALM was used to evaluate exposure to lead in soil for the Security Guard/Maintenance Worker and Resident Subsistence Farmer Adult. The ALM was not used to evaluate the National Guard Trainee, Fire/Dust Suppression Worker, or Hunter/Fisher because the exposure frequency of these receptors does not meet the steady-state assumptions of the model [i.e., the first-order elimination half-life of lead of approximately 30 days requires a constant lead intake over a duration of 90 days to reach quasi-steady state. Shorter exposures are expected to produce oscillations in PbB concentrations as a result of absorption and subsequent clearance of lead between each exposure event (EPA 2003b)].

The Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children (available at http://www.epa.gov/superfund/programs/lead/ieubk.htm) was used to evaluate the On-Site Resident Subsistence Farmer Child. The IEUBK model is used to predict the risk of elevated PbB levels in children (under the age of seven) that are exposed to environmental lead (Pb) from many sources. The model also predicts the risk (e.g., probability) that a typical child, exposed to specified media PbB concentrations, will have a PbB level greater or equal to the level associated with adverse health effects (10 µg/dL). Default input parameters were used. Input parameters and results of this model are provided in Appendix L, Table L-10.

6.5 RISK CHARACTERIZATION

The purpose of the risk characterization is to evaluate the information obtained through the exposure and toxicity assessments to estimate potential risks and hazards. Potential carcinogenic effects are characterized by using projected intakes and chemical-specific, dose-response data (i.e., CSFs) to estimate the probability that an individual will develop cancer over a lifetime. Potential non-carcinogenic effects are characterized by comparing projected intakes of contaminants to toxicity values (i.e., RfDs). The numerical risk and hazard estimates presented in this chapter must be interpreted in the context of the uncertainties and assumptions associated with the risk assessment process and with the data upon which the risk estimates are based.

6.5.1 Methodology

Risk characterization integrates the findings of the exposure and toxicity assessments to estimate the potential for receptors to experience adverse effects as a result of exposure to contaminated media at RQL.

6.5.1.1 Risk characterization for carcinogens

For carcinogens, risk is expressed as the probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as the incremental lifetime cancer risk (ILCR), or the increased chance of cancer above the normal background rate of cancer. In the United States, the background chance of contracting cancer is a little more than 3 in 10, or 3×10^{-1} (American Cancer Society 2003). The calculated ILCRs are compared to the range specified in the National Oil and Hazardous Substances Pollution Contingency Plan of 10^{-6} to 10^{-4}, or 1-in-1 million to 1-in-10,000 exposed persons developing cancer (EPA 1990a). ILCRs below 10^{-6} are considered acceptable; ILCRs above 10^{-4} are considered unacceptable. The range between 10^{-6} and 10^{-4} is of concern, and any decisions to address ILCRs further in this range, either through additional study or engineered control measures, should account for the uncertainty in the risk estimates.

The ILCR is calculated using the equation below (EPA 1989b):

$$\mathrm{ILCR} = I \times \mathrm{CSF} \qquad \textbf{(6-21)}$$

where

I = chronic daily intake or DAD calculated in the exposure assessment (mg/kg-day),
CSF = cancer slope factor $(\text{mg/kg-day})^{-1}$.

The above linear equation is valid only at low risk levels (i.e., below estimated risks of 1.0E-02). For higher risks, the one-hit equation below (EPA 1989b) is used:

$$\mathrm{ILCR} = 1 - \exp(-I \times \mathrm{CSF}) \qquad \textbf{(6-22)}$$

For a given exposure pathway, the total risk to a receptor exposed to several carcinogenic COPCs is the sum of the ILCRs for each carcinogen, as shown in Equation 6-23 below:

$$\mathrm{ILCR}_{\mathrm{total}} = \Sigma \mathrm{ILCR}_{i} \qquad \textbf{(6-23)}$$

where

$ILCR_{total}$ = total probability of cancer incidence associated with all carcinogenic COPCs,
$ILCR_i$ = ILCR for the i^{th} COPC.

In addition to summing risks across all carcinogenic COPCs, risks are summed across all exposure pathways for a given environmental medium (e.g., ingestion, inhalation, and dermal contact with surface soil). Per EPA (1989b) guidance, "there are two steps required to determine whether risks or hazard indices for two or more pathways should be combined for a single exposed individual or group of individuals. The first is to identify reasonable exposure pathway combinations. The second is to examine whether it is likely that the same individuals would consistently face the "reasonable maximum exposure" (RME) by more than one pathway." It is reasonable to assume the same individual may be exposed at the RME by multiple pathways to a given exposure medium. For example, a Security Guard/Maintenance Worker present at RQL can reasonably be assumed to both ingest surface soil and inhale contaminated dust from this EU.

6.5.1.2 Risk characterization for non-carcinogens

In addition to developing cancer from exposure to contaminants, an individual may experience other toxic effects. The term "toxic effects" is used here to describe a wide variety of systemic effects ranging from minor irritations, such as eye irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with toxic (i.e., non-carcinogenic) chemicals are evaluated by comparing an estimated exposure (i.e., intake or dose) from site media to an acceptable exposure expressed as an RfD. The RfD is the threshold level below which no toxic effects are expected to occur in a population, including sensitive subpopulations. The ratio of intake over the RfD is the HQ (EPA 1989b) and is calculated as:

$$HQ = I/RfD \qquad \textbf{(6-24)}$$

where

I = daily intake or DAD of a COPC (mg/kg-day),
RfD = reference dose (mg/kg-day).

The HQs for each COPC are summed to obtain a hazard index (HI), as shown below:

$$HI = \Sigma HQ_i \qquad \textbf{(6-25)}$$

where

HI = hazard index for all toxic effects,
HQ_i = hazard quotient for the i^{th} COPC.

An HI greater than 1 has been defined as the level of concern for potential adverse non-carcinogenic health effects (EPA 1989b). This approach differs from the probabilistic approach used to evaluate carcinogens. An HQ of 0.01 does not imply a 1-in-100 chance of an adverse effect but indicates only that the estimated intake is 100 times less than the threshold level at which adverse health effects may occur.

In addition to summing hazards across all COPCs, hazards are summed across all exposure pathways for a given environmental medium.

6.5.1.3 Identification of COCs

COCs are defined as those contaminants that have an ILCR greater than 1×10^{-6} and/or an HQ greater than 1.

6.5.2 Results

Estimated risks for RQL are evaluated for the Security Guard/Maintenance Worker as the representative receptor exposed to surface soil. Surface soil data are defined as coming from 0 to 1 ft bgs. Risks are also calculated for four additional receptors [National Guard Dust/Fire Control Worker, National Guard Trainee, Hunter/Fisher, and Resident Subsistence Farmer (adult and child)] to provide additional information for consideration in the FS. Detailed hazard and risk results are presented in Tables L-11 through L-21 for all exposure media for all five receptors evaluated. Results are summarized in the following sections for the representative receptor (Security Guard/Maintenance Worker) and the Resident Subsistence Farmer (to provide a baseline for unrestricted release of the property).

The EU is evaluated to provide an estimate of risk from a RME. The RME incorporates a reasonable estimate of the concentration to which a receptor may be exposed (UCL_{95} on the mean). The use of the UCL_{95} on the mean as the EPC implies that a receptor may come into contact with contaminants throughout the EU.

6.5.2.1 Surface soil risks and hazards

Surface Soil – Direct Contact

Detailed hazard and risk results for all five receptors' direct contact with COPCs in surface soil are presented in Tables L-11 and L-12. Direct contact includes incidental ingestion of soil, inhalation of VOCs and particulates (i.e. dust) from soil, and dermal contact with soil. Hazard and risk results for the Security Guard/Maintenance Worker and Resident Subsistence Farmer direct contact with COPCs in surface soil are summarized in Table 6-7.

The total HI for the Security Guard/Maintenance Worker exposed to surface soil is 0.23, which is below the threshold of 1.0; thus, no non-carcinogenic surface soil COCs are identified at RQL for this receptor.

The total risk across all COPCs for the Security Guard/Maintenance Worker exposed to surface soil is 2.1E-03, coming predominantly from PAHs. Nine carcinogenic surface soil COCs are identified, including

- one metal (arsenic),
- seven PAHs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and
- one SVOC (carbazole).

Five of the nine carcinogenic surface soil COCs have risks in excess of Ohio EPA's level of concern of 1.0E-05: benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene. Note that one sample (RQL-026) highly influences the carcinogenic risk results, as the MDC comes from this one sample for all eight organic COCs. For these eight COCs, the next largest concentration is 1 to 2 orders of magnitude lower than the concentrations detected in sample RQL-026.

Table 6-7. Summary of Surface Soil Risks and Hazards for Direct Contact at the Ramsdell Quarry Landfill

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Security Guard/Maintenance Worker	2.3E-01	None	2.1E-03	Arsenic
				Benz(*a*)anthracene
				Benzo(*a*)pyrene
				Benzo(*b*)fluoranthene
				Benzo(*k*)fluoranthene
				Carbazole
				Chrysene
				Dibenz(*a,h*)anthracene
				Indeno(1,2,3-*cd*)pyrene
Resident Subsistence Farmer (Adult)	5.4E-01	None	4.6E-03	Arsenic 2,6-Dinitrotoluene Benz(*a*)anthracene Benzo(*a*)pyrene Benzo(*b*)fluoranthene Benzo(*k*)fluoranthene Carbazole Chrysene Dibenz(*a,h*)anthracene Indeno(1,2,3-*cd*)pyrene
Resident Subsistence Farmer (Child)	2.4E+00	None	2.8E-03	Arsenic 2,6-Dinitrotoluene Benz(*a*)anthracene Benzo(*a*)pyrene Benzo(*b*)fluoranthene Benzo(*k*)fluoranthene Carbazole Chrysene Dibenz(*a,h*)anthracene Indeno(1,2,3-*cd*)pyrene

COC = Chemical of concern.
HI = Hazard index.
ILCR = Incremental lifetime cancer risk.

Note also that the EPC for arsenic is 15.3 mg/kg, which is below the arsenic background soil concentration of 15.4 mg/kg. Thus, the cancer risk related to arsenic at RQL does not exceed the cancer risk for arsenic estimated from the facility-wide background.

The total HIs for the Resident Subsistence Farmer Adult and Child exposed to surface soil are 0.54 and 2.4, respectively. The total HI for the Farmer Child is above the threshold of 1.0; however, no individual COPCs have HQs above 1.0. The largest individual HQ is 0.7 for arsenic. Thus, no non-carcinogenic surface soil COCs are identified at RQL for this receptor.

The total risks across all COPCs for the Resident Subsistence Farmer Adult and Child exposed to surface soil are 4.6E-03 and 2.8E-03, respectively, coming predominantly from PAHs. Ten carcinogenic surface soil COCs are identified, including

- one metal (arsenic),
- one explosive (2,6-dinitrotoluene),
- seven PAHs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and
- one SVOC (carbazole).

Seven of the ten carcinogenic surface soil COCs have risks in excess of Ohio EPA's level of concern of 1.0E-05: arsenic, benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(k)fluoranthene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene. Note that one sample (RQL-026) highly influences the carcinogenic risk results, as the MDC comes from this one sample for all nine organic COCs. For these nine COCs, the next largest concentration is 1 to 2 orders of magnitude lower than the concentrations detected in sample RQL-026. In the case of 2,6-dinitrotoluene, all other samples are non-detect with a detection limit more than one order of magnitude lower than this single detect.

Note also that the EPC for arsenic is 15.3 mg/kg, which is below the arsenic background soil concentration of 15.4 mg/kg. Thus, the cancer risk related to arsenic at RQL does not exceed the cancer risk for arsenic estimated from the facility-wide background.

Surface Soil – Indirect Contact

Detailed hazard and risk results for the Resident Subsistence Farmer indirect contact with COPCs in surface soil are presented in Tables L-13 and L-14 and summarized in Table 6-8. Indirect contact includes ingestion of venison, beef, milk, and vegetables. The Resident Subsistence Farmer is the only receptor potentially exposed by these indirect pathways.

The total HIs for the Resident Subsistence Farmer Adult and Child exposed to surface soil via indirect contact are 65 and 300, respectively. Seventeen non-carcinogenic surface soil COCs are identified at RQL for food ingestion by a Resident Subsistence Farmer. The total risks across all COPCs for the Resident Subsistence Farmer Adult and Child exposed to surface soil are 4.1E-01 and 4.6E-01, respectively, coming predominantly from PAHs. Eleven carcinogenic surface soil COCs are identified.

These risks are driven primarily by ingestion of vegetables followed by milk and beef ingestion. Ingestion of venison has a negligible contribution to hazard and risk.

Surface soil lead modeling results

Lead was identified as a surface soil COPC at RQL. Lead model results for the Security Guard/Maintenance Worker, and Resident Subsistence Farmer (adult and child) are provided in Appendix L Tables L-8 through L-10. For the Security Guard/Maintenance Worker exposed to surface soil, the estimated probability of fetal PbB concentrations exceeding acceptable levels ranged from 7 to 9% at RQL (see Table L-8). For the Resident Subsistence Farmer Adult, the estimated probability of fetal PbB concentrations exceeding acceptable levels ranged from 12 to 14.5% at RQL (see Table L-9). For the Resident Subsistence Farmer Child, the estimated probability of PbB concentrations exceeding acceptable levels is 71.2% at RQL (see Table L-10).

Table 6-8. Summary of Surface Soil Risks and Hazards for Ingestion of Foodstuffs at the Ramsdell Quarry Landfill

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (Adult)	6.5E+01	Al, Sb, As, Cd, Cr, Cu, Tl, Vn 1,3-Dinitrobenzene 2,4,6-Trinitrotoluene 2,6-Dinitrotoluene 2-Methylnaphthalene Dibenzofuran Fluoranthene Pyrene	4.1E-01	As 2,4,6-Trinitrotoluene 2,6-Dinitrotoluene Benz(*a*)anthracene Benzo(*a*)pyrene Benzo(*b*)fluoranthene Benzo(*k*)fluoranthene Carbazole Chrysene Dibenz(*a,h*)anthracene Indeno(1,2,3-*cd*)pyrene
Resident Subsistence Farmer (Child)	3.0E+02	Al, Sb, As, Cd, Cr, Cu, Tl, Vn 1,3-Dinitrobenzene 2,4,6-Trinitrotoluene 2,6-Dinitrotoluene 2-Methylnaphthalene Dibenzofuran Fluoranthene Fluorene Naphthalene Pyrene	4.6E-01	As 2,4,6-Trinitrotoluene 2,6-Dinitrotoluene Benz(*a*)anthracene Benzo(*a*)pyrene Benzo(*b*)fluoranthene Benzo(*k*)fluoranthene Carbazole Chrysene Dibenz(*a,h*)anthracene Indeno(1,2,3-*cd*)pyrene

COC = Chemical of concern.
HI = Hazard index.
ILCR = Incremental lifetime cancer risk.

6.5.2.2 Groundwater risks and hazards

Detailed hazard and risk results for all applicable receptors' (i.e., Resident Subsistence Farmer and National Guard Trainee) direct contact with COPCs in groundwater are presented in Tables L-15 and L-16. Hazard and risk results for the Resident Subsistence Farmer direct contact with COPCs in groundwater are summarized in Table 6-9. The Security Guard/Maintenance Worker is not exposed to groundwater. Direct contact includes drinking water ingestion of groundwater, inhalation of VOCs from groundwater during household water use, and dermal contact with groundwater during bathing/showering.

Table 6-9. Summary of Groundwater Risks and Hazards at the Ramsdell Quarry Landfill

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (Adult)	4.6E+00	Manganese	1.2E-04	Arsenic
Resident Subsistence Farmer (Child)	1.6E+01	Arsenic Manganese	8.4E-05	Arsenic

COC = Chemical of concern.
HI = Hazard index.
ILCR = Incremental lifetime cancer risk.

Two groundwater COCs (arsenic and manganese) are identified for the Resident Subsistence Farmer; both are inorganics.

6.5.2.3 Sediment risks and hazards

Detailed hazard and risk results for all applicable receptors (i.e., Resident Subsistence Farmer, National Guard Trainee, National Guard Fire/Dust Control Worker, and Hunter/Fisher) direct contact with COPCs in sediment are presented in Tables L-17 and L-18. Hazard and risk results for the Resident Subsistence Farmer direct contact with COPCs in sediment are summarized in Table 6-10. The Security Guard/Maintenance Worker is not exposed to sediment. Direct contact includes incidental ingestion of sediment, inhalation of VOCs and particulates (i.e., dust) from sediment, and dermal contact with sediment.

Table 6-10. Summary of Sediment Risks and Hazards for Direct Contact at the Ramsdell Quarry Landfill

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (Adult)	5.1E-01	None	5.4E-05	Arsenic Benzo(a)pyrene
Resident Subsistence Farmer (Child)	3.0E+00	Arsenic	6.1E-05	Arsenic Benzo(a)pyrene

COC = Chemical of concern.
HI = Hazard index.
ILCR = Incremental lifetime cancer risk.

Two sediment COCs [arsenic and benzo(*a*)pyrene] are identified for the Resident Subsistence Farmer.

6.5.2.4 Surface water risks and hazards

Detailed hazard and risk results for all applicable receptors (i.e., Resident Subsistence Farmer, National Guard Trainee, National Guard Fire/Dust Control Worker, and Hunter/Fisher) direct contact with COPCs in surface water are presented in Tables L-19 and L-20. Hazard and risk results for the Resident Subsistence Farmer direct contact with COPCs in surface water are summarized in Table 6-11. The Security Guard/Maintenance Worker is not exposed to surface water. Direct contact includes incidental ingestion of surface water and dermal contact with surface water.

Table 6-11. Summary of Surface Water Risks and Hazards for Direct Contact at the Ramsdell Quarry Landfill

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (Adult)	1.3E+00	None	3.3E-05	Arsenic Aldrin
Resident Subsistence Farmer (Child)	3.3E+00	Manganese	2.3E-05	Arsenic Aldrin

COC = Chemical of concern.
HI = Hazard index.
ILCR = Incremental lifetime cancer risk.

Three sediment COCs (arsenic, manganese, and aldrin) are identified for the Resident Subsistence Farmer.

6.5.2.5 Wildfowl ingestion risks and hazards

Detailed hazard and risk results for the Hunter/Fisher from ingestion of wildfowl for all COPCs in sediment and surface water are presented in Table L-21. The Hunter/Fisher is the only receptor potentially exposed by ingestion of wildfowl.

The total HI for the Hunter/Fisher via ingestion of wildfowl is 9.0 and the total risk across all COPCs is 8.9E-04. Seven COCs are identified [aluminum, arsenic, cadmium, chromium, thallium, vanadium, and benzo(*a*)pyrene].

6.6 UNCERTAINTY ANALYSIS

This section identifies the uncertainties associated with each step of the risk assessment process, where possible. Uncertainties are not mutually exclusive.

6.6.1 Uncertainties Associated with the Data Evaluation

Although the data evaluation process used to select COPCs adheres to established procedures and guidance, it also requires making decisions and developing assumptions on the basis of historical information, disposal records, process knowledge, and best professional judgment about the data. Uncertainties are associated with all such assumptions. The background concentrations and PRGs used to screen analytes are also subject to uncertainty.

Another area of uncertainty involves the qualitative evaluation (and elimination from further consideration) of essential nutrients, many of which have no available toxicity values. In addition, the toxicity values used in the derivation of PRGs are subject to change, as additional information becomes available from scientific research. These periodic changes in toxicity values may cause the PRG values to change as well.

Some unavoidable uncertainty is associated with the contaminant concentrations detected and reported by the analytical laboratory. The quality of the analytical data used in the risk assessment depends on the adequacy of the set of procedures that specifies how samples are selected and handled and how strictly these procedures are followed QA/QC procedures within the laboratories are used to minimize uncertainties; however, sampling errors, laboratory analysis errors, and data analysis errors can occur.

Some current analytical methods are limited in their ability to achieve detection limits at or below risk-based screening levels (i.e., PRG concentrations). Under these circumstances, it is uncertain whether the true concentration is above or below the PRGs, which are protective of human health. When analytes are on the COPC list and have a mixture of detected and non-detected concentrations, risk calculations may be affected by these detection limits. Risks may be overestimated as a result of some sample concentrations being reported as non-detected at the method detection limit (MDL), which may be greater than the PRG concentration (when the actual concentration may be much smaller than the MDL). Risks may also be underestimated because some analytes that are not detected in any sample are removed from the COPC list. If the concentrations of these analytes are below the MDL but are above the PRG, the risk from these analytes would not be included in the risk assessment results.

In the data assessment process, elevated levels of common laboratory contaminants [e.g., bis(2-ethylhexyl)phthalate] can be evaluated to see if the detected concentrations are likely to be “false positives” (i.e., at high concentrations due to laboratory interference). This process involves a check against the concentrations detected in the associated laboratory method blank.

6.6.2 Uncertainties Associated with the Exposure Assessment

Uncertainty is also introduced through the process of estimating representative exposure concentrations in the analyzed exposure media. Analytical results are used to calculate a mean concentration and the UCL_{95} on the mean concentration. The smaller of the MDC and the UCL_{95} concentration is used as the EPC for this HHRA. This method may underestimate the EPC for small data sets from areas with a high degree of variability in contaminant concentrations.

Moderate uncertainty can be introduced in the data aggregation process for estimating a representative exposure concentration in the exposure media. A statistical test (the Shapiro-Wilk test) is performed to determine whether the concentration data are best described by a normal or lognormal distribution. Each COPC's mean and UCL_{95} on the mean concentrations are calculated using both detected values and one-half of the reported detection limit for samples without a detected concentration. The EPC is the smaller of the MDC or the calculated UCL_{95}. This method may moderately overestimate the exposure concentration. In addition, when the resulting individual contaminant risks are summed to provide a total ILCR or HI, the compounding conservatism of this method for estimating EPCs will likely result in an overestimate of the total risk.

Representative exposure concentrations are calculated in this HHRA based on the assumption that the samples collected from the EU are truly random samples. This assumption may not be met for RQL. Sample locations may be biased to identify areas of highest contaminant concentrations.

In addition, in the evaluation of the various media, environmental concentrations are assumed to be constant (i.e., concentrations are not reduced by loss due to natural removal processes such as volatilization, leaching, and/or biodegradation). This assumption is a source of uncertainty, especially for groundwater and surface water.

At best, quantification of exposure provides an estimate of the chemical intake for various exposure pathways identified at the site. Several uncertainties associated with the various components of the exposure assessment include uncertainties about the exposure pathway equations, exposure parameters, land use scenarios, representative exposure concentrations, and sampling and analysis of the media.

For each primary exposure pathway chosen for analysis in this HHRA, assumptions are made concerning the exposure parameters (e.g., amount of contaminated media a receptor can be exposed to and intake rates for different routes of exposure) and the routes of exposure. In the absence of site-specific data, the assumptions used are consistent with Ohio EPA-approved default values, which are assumed to be representative of potentially exposed populations (USACE 2004b). All contaminant exposures are assumed to be from site-related exposure media (i.e., no other sources contribute to the receptor's health risk).

The most relevant receptor evaluated at RQL is the Security Guard/Maintenance Worker. Exposure parameters for this scenario are outlined in Table 5 of the FWHHRAM (USACE 2004b) and are protective of potential receptors at RQL. This scenario assumes a Security Guard/Maintenance Worker patrols Ramsdell Quarry every day for 1 hr. Although a Security Guard is not currently exposed to contaminated media at Ramsdell Quarry on a daily basis, the potential exposure of this receptor is considered protective of receptors with more irregular exposure (e.g., a wildlife ecologist who spends several days at the site once every few years, security personnel who may periodically evaluate the site, or workers engaged in periodic maintenance).

Note that for the dermal contact with soil pathway, no exposure time is included in the equation. This is based on the assumption that the receptor may not bathe (i.e., remove the soil in contact with the skin surface) for 24 hr following the initial exposure; therefore, the receptor is actually exposed to soil contaminants for 24 hr/day. This may overestimate the risk associated with dermal contact with soil or sediment. This fact is especially important when the dermal pathway is the major contributor to the risks and/or hazards (e.g., for PAHs). Because the Security Guard/Maintenance Worker (exposed 1 hr/day for 250 days/year) is used as a surrogate to represent receptors with less regular exposure (e.g., a wildlife ecologist who spends several days at the site once every few years, security personnel who may periodically evaluate the site, or workers engaged in periodic maintenance), this assumption will overestimate dermal exposure to actual anticipated receptors at RQL. This is because, from a dermal exposure standpoint, a receptor exposed 1 hr/day for 5 days is worse than a receptor exposed 5 hrs/day for 1 day because exposure time is assumed to be 24 hrs/day for both.

Most exposure parameters have been selected so that errors occur on the side of conservatism. When several of these upper-bound values are combined in estimating exposure for any one pathway, the resulting risks can be in excess of the 99th percentile and, therefore, outside of the range that may be reasonably expected. Therefore, the consistent conservatism employed in the estimation of these parameters generally leads to overestimation of the potential risks.

While a Land Use Plan has been drafted for RTLS [as summarized in the FWHHRAM (USACE 2004b)], and OHARNG will control the property, there is uncertainty in the details of the future land use (e.g., if the perimeter fence is not maintained, then a trespasser could enter the property or if hunting restrictions are relaxed, then a hunter could utilize the site). To address this uncertainty, additional receptors (e.g., Hunter/Fisher, National Guard Trainee, and Fire/Dust Suppression Worker) are included in the risk assessment. There is little to no uncertainty associated with the assumption that RVAAP will not be released for residential use; however, a Resident Subsistence Farmer receptor was evaluated to provide a baseline scenario.

6.6.3 Uncertainties Associated with the Toxicity Assessment

The methodology used to develop a non-carcinogenic toxicity value (RfD or RfC) involves identifying a threshold level below which adverse health effects are not expected to occur. The RfD and RfC values are generally based on studies of the most sensitive animal species tested (unless adequate human data are available) and the most sensitive endpoint measured. Uncertainties exist in the experimental data set for such animal studies. These studies are used to derive the experimental exposure representing the highest dose level tested at which no adverse effects are demonstrated [i.e., the no-observed-adverse-effect level (NOAEL)]; in some cases, however, only a lowest-observed-adverse-effect level (LOAEL) is available. The RfD and/or RfC is derived from the NOAEL (or LOAEL) for the critical toxic effect by dividing the NOAEL (or LOAEL) by uncertainty factors. These factors usually are in multipliers of 10, with each factor representing a specific area of uncertainty in the extrapolation of the data. For example, an uncertainty factor of 100 is typically used when extrapolating animal studies to humans. Additional uncertainty factors are sometimes necessary when other experimental data limitations are found. Because of the large uncertainties (10 to 10,000) associated with some RfD or RfC toxicity values, exact safe levels of exposure for humans are not known. For non-carcinogenic effects, the amount of human variability in physical characteristics is important in determining the risks that can be expected at low exposures and in determining the NOAEL (EPA 1989b).

The toxicological data (CSFs and RfDs) for dose-response relationships of chemicals are frequently updated and revised, which can lead to overestimation or underestimation of risks. These values are often extrapolations from animals to humans, and this can also causes uncertainties in toxicity values because differences can exist in chemical absorption, metabolism, excretion, and toxic response between animals and humans.

EPA considers differences in body weight, surface area, and pharmacokinetic relationships between animals and humans to minimize the potential to underestimate the dose-response relationship; as a result, more conservatism is usually incorporated into these steps. In particular, toxicity factors that have high uncertainties may change as new information is evaluated. Therefore, a number of the COCs—particularly those with high uncertainties—may be subject to change. Finally, the toxicity of a contaminant may vary significantly with the chemical form present in the exposure medium. For example, risks from metals may be overestimated because they are conservatively assumed to be in their most toxic forms.

The carcinogenic potential of a chemical can be estimated through a two-part evaluation involving (1) a WOE assessment to determine the likelihood that a chemical is a human carcinogen, and (2) a slope factor assessment to determine the quantitative dose-response relationship. Uncertainties occur with both assessments. Chemicals fall into one of five groups on the basis of WOE studies of humans and laboratory animals (EPA 2005): (1) Group A – known human carcinogen; (2) Group B – probable human carcinogen based on limited human data or sufficient evidence in animals, but inadequate or no evidence in humans; (3) Group C – possible human carcinogens; (4) Group D – not classified as to human carcinogenicity; and (5) Group E – evidence of no carcinogenic effects in humans. Two COPCs identified at RQL are Group A carcinogens (arsenic and chromium, evaluated as hexavalent chromium), ten are Group B carcinogens [cadmium; 2,6-DNT; benz(*a*)anthracene; benzo(*a*)pyrene; benzo(*b*)fluoranthene; benzo(*k*)fluoranthene; carbazole; chrysene; dibenz(*a,h*)anthracene; and indeno(1,2,3-*cd*)pyrene], and one is classified as Group C (2,4,6-TNT).

The CSF for a chemical is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. It is used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The slope factor is derived by applying a mathematical model to extrapolate from a relatively high, administered dose to animals to the lower exposure levels expected for humans. The slope factor represents the UCL_{95} on the linear component of the slope (generally the low-dose region) of the tumorigenic dose-response curve. A number of low-dose extrapolation models have been developed, and EPA generally uses the linearized multistage model in the absence of adequate information to support other models.

For several analytes, no toxicity information for either the non-carcinogenic or carcinogenic health effects to humans is available in EPA's IRIS (EPA 2005) or HEAST (EPA 1997c). Therefore, until and unless additional toxicity information allows the derivation of toxicity factors, potential risk from certain chemicals cannot be quantified. COPCs falling into this category include sulfate; 2-amino-4,6-DNT; 4-amino-2,6-DNT; acenaphthylene; benzo(*g,h,i*)perylene; nitrocellulose; nitroglycerin; and phenanthrene.

Uncertainties are associated with the GAF values used to modify the oral toxicity values to evaluate dermal toxicity. Similar uncertainties are associated with the TEF values used to estimate risks from exposure to PAHs. Many potential uncertainties are associated with the toxicity data used in this HHRA and can affect the risk, hazard, and COC determinations.

6.6.4 Uncertainties Associated with the Risk Characterization

Risk assessment, as a scientific activity, is subject to uncertainty. This is true even though the methodology used in this HHRA follows EPA guidelines. As noted previously, the risk evaluation in this report is subject to uncertainty pertaining to sampling and analysis, selection of COPCs, exposure estimates, and availability and quality of toxicity data.

6.6.4.1 Evaluation of total risk

Uncertainties related to the summation of HQs and ILCRs across chemicals and pathways are a primary uncertainty in the risk characterization. In the absence of information on the toxicity of specific chemical mixtures, it is assumed that ILCRs and HQs are additive (i.e., cumulative) (EPA 1989b). The limitations of this approach for non-carcinogens are (1) the effects of a mixture of chemicals are generally unknown;

it is possible that the interactions could be synergistic, antagonistic, or additive; (2) the RfDs have different accuracy and precision and are not based on the same severity or effect; and (3) HQ or intake summation is most properly applied to compounds that induce the same effects by the same mechanism. Therefore, the potential for occurrence of non-carcinogenic effects can be overestimated for chemicals that act by different mechanisms and on different target organs.

Limitations of the additive risk approach for multiple carcinogens are (1) the chemical-specific slope factors represent the upper 95th percentile estimate of potency; therefore, summing individual risks can result in an excessively conservative estimate of total lifetime cancer risk; and (2) the target organs of multiple carcinogens may be different, so the risks would not be additive. In the absence of data, additivity for ILCRs and HQs is assumed for this HHRA. However, because total risks and HIs are usually driven by a few chemicals, segregation of risks and HIs by target organ would most likely not have resulted in significantly different outcomes.

Additional uncertainty can be associated with the method of selection of COCs. For this HHRA, COCs are selected for a given medium/land use scenario as chemicals with individual ILCRs ≥ 1.0E-06 and/or individual HQs ≥ 1.0 for any medium/land use scenario.

Potential risks and hazards are not determined for the eight COPCs [sulfate; 2-amino-4,6-DNT; 4-amino-2,6-DNT; acenaphthylene; benzo(*g,h,i*)perylene; nitrocellulose; nitroglycerin; and phenanthrene] that could not be evaluated quantitatively due to the lack of toxicity information and/or values. This results in uncertainty that could underestimate the total risk/hazard to human health.

6.6.4.2 Contribution from background

Background concentrations of several COPCs may contribute significantly to the calculated risk, as discussed below.

Carbazole is released to the atmosphere in emissions from waste incineration, tobacco smoke, aluminum manufacturing, and rubber, petroleum, coal, and wood combustion. If released to the atmosphere, vapor-phase carbazole is rapidly degraded by photochemically produced hydroxyl radicals (estimated half-life of 3 hr). In the particulate phase, the rate of degradation depends upon the adsorbing substrate. Substrates containing carbon (>5%) stabilize carbazole and permit long-range atmospheric transport. Physical removal from air and transport to soil via wet and dry deposition is important. If released to soil, environmental substrates that commonly adsorb carbazole may limit or prevent photolysis. Biodegradation in soil should be the dominant fate process providing the presence of specific degrading bacteria in the microbial community (biodegradation half-life of 4.3 min to 6.2 hr in screening studies). If released to water, volatilization and bioconcentration in aquatic organisms will not be important. Biodegradation and photolysis should be the dominant fate processes in water systems providing specific degrading bacteria and sufficient sunlight. However, carbazole may partition from the water column to sediment and suspended matter, thus limiting the rate of photolysis. Human exposure to background sources of carbazole occurs through inhalation of contaminated air and consumption of water and charbroiled food.

PAHs can be introduced to the environment by residential wood burning, cooking foods, and combustion of fossil fuels, as well as discharges from industrial plants, waste water treatment plants, and escape from waste storage containers. Other industrial sources of PAHs are machine lubricating, cutting, and color printing oils. PAHs are found in creosote, which is used as a wood preservative. PAHs are also found in coal tar, which is used in roofing, surface coatings, and as a binder for aluminum-smelting electrons in the aluminum-reduction process. PAHs are released to the environment in nature by volcanic activity and forest fires. Only a few PAHs are produced commercially. In general, PAHs are unintentionally generated during combustion or pyrolysis processes. PAHs have a wide range of vapor pressures, and, if released to the air, may exist in both vapor and particulate phases. In general, PAHs with three rings exist predominately in the vapor phase, those with four rings can exist in both vapor and particulate phase, and those with five or more rings exist predominately in the particulate phase. Vapor-phase PAHs are degraded in the atmosphere by reaction with photochemically produced hydroxyl radicals; calculated half-lives for this reaction are generally less than 1 day. Under environmental conditions, PAHs with higher molecular weights are almost completely adsorbed onto fine particles and lower molecular weight PAHs are partially adsorbed; this adsorption may attenuate the degradation of PAHs. Particulate-phase PAHs may be removed from the air by wet and dry deposition. Some PAHs can undergo direct photolysis (>290 nm). If released to soil, Koc values in the range of 1E+03 to 1E+04 for low molecular weight (MW 152 to 178) PAHs, 1E+04 for medium molecular weight (MW 202) PAHs, and 1E+5 to 1E+6 for high molecular weight (228 to 278) PAHs, indicate that low molecular weight PAHs are expected to have slight to no mobility in soil and medium, and high molecular weight PAHs are expected to be immobile in soil. Volatilization of PAHs from moist soil surfaces may be an important fate process for low and medium molecular weight PAHs, given Henry's Law constants in the range of 1E-03 to 1E-05 atm-cu m/mole (low molecular weight PAHs) and of 1E-06 atm-cu m/mole (medium molecular weight PAHs). Volatilization of high molecular weight PAHs is not expected to be an important fate process, given Henry's Law constants in the range of 1E-05 to 1E-08 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization for those PAHs with Henry's Law constants greater than 1E-03 atm-cu m/mole. PAHs are not expected to volatilize from dry soil surfaces. In general, vapor pressures of PAHs are less than 1 mm Hg, and vapor pressures of PAHs decrease with increasing molecular weight. Breakdown in soil generally takes weeks to months for PAHs with three rings, primarily by action of microorganisms. PAHs with four or more rings are generally resistant to biodegradation. If released into water, PAHs are expected to adsorb to suspended solids and sediment. In general, PAHs with higher molecular weights will adsorb more strongly than those with lower molecular weights. In aquatic environments, low molecular weight PAHs generally biodegrade relatively rapidly, while PAHs with more than three rings appear to be extremely stable to biodegradation. Volatilization of PAHs from water surfaces may be an important fate process for low and medium molecular weight PAHs, given Henry's Law constants in the range of 1E-03 to 1E-05 atm-cu m/mole (low molecular weight PAHs) and of 1E-06 atm-cu m/mole (medium molecular weight PAHs). Volatilization of high molecular weight PAHs from water surfaces is not expected to be an important fate process, given Henry's Law in the range of 1E-05 to 1E-08 atm-cu m/mole. Any volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column. Bioaccumulation factors for PAHs for fish and crustaceans have been reported in the range of 10 to 10,000. Compounds with bioconcentration factors greater than 1,000 have a high potential for bioaccumulation. In general, bioaccumulation is higher for higher molecular weight PAHs than for lower molecular weight PAHs, although some specific compounds [e.g., benzo(*a*)pyrene] are susceptible to metabolism in some aquatic organisms. Hydrolysis is not expected to be an important environmental fate process, because PAHs lack functional groups that hydrolyze under environmental conditions. Monitoring data indicate that the largest exposure to PAHs to the general population is through the ingestion of foods. Exposure may also occur from drinking water and inhalation of ambient air containing exhaust from the combustion of fuels or cigarette smoke. Occupational exposure may occur through inhalation and dermal contact with PAHs.

Arsenic is a naturally occurring element and is found in a number of sulfide ores. It constitutes 5E-04% of the earth's crust. Arsenic can be released to the environment from natural sources, including volcanoes and erosion of mineral deposits. Human activities (e.g., chemical production and use, metal smelting, coal combustion, and waste disposal) result in release of arsenic, causing substantial environmental contamination (ATSDR 1993) (HSDB 2001).

Most human releases of arsenic are to land or soil, primarily from pesticides or solid wastes. Substantial amounts of arsenic are also released to air and water. Arsenic production and use of arsenic-containing products are the major sources of arsenic releases to the air from human activities. Arsenic is released to water by natural weathering processes, by discharge from industrial facilities, by leaching from landfills or soil, and by urban runoffs (ATSDR 1993).

Arsenic pollution is widespread. Human exposure to both naturally occurring and manufactured arsenic may occur through air, food, and water (Bingham et al, 2001). Arsenic is a widespread soil contaminant because of past use of arsenic-containing pesticides. Native soil concentrations of arsenic are typically in the range of 1.0-40 ppm, and in extreme states, as high as 0.1 to 500 ppm (Dragun 1988). Arsenic content of soils in Ohio range from 0.5 to 56 mg/kg (Cox and Colvin 1996) and the USGS's Certificate of Analysis of the Devonian Ohio Shale estimates arsenic concentrations of 68.5 mg/kg are naturally present in bedrock shales (USGS 2004).

6.7 REMEDIAL GOAL OPTIONS

To support the remedial alternative selection process, RGOs were developed for all chemicals identified as COCs in the direct exposure pathways for this HHRA. For each exposure medium, RGOs are calculated for all COCs for that medium regardless of receptor. For example, 2,6-dinitrotoluene was identified as a COC in surface soil for a Resident Subsistence Farmer but not for the Security Guard/Maintenance Worker or any other receptor; however, surface soil RGOs are calculated for 2,6-dinitrotoluene for all five receptors. RGOs are calculated for direct contact COCs only because the models used to estimate risk from food ingestion are extremely conservative and are not appropriate for calculating RGOs because they do not account for exposures to clean or contaminated media outside RQL and RVAAP. RGOs are calculated using the methodology presented in RAGS Part B (EPA 1991b) while incorporating site-specific exposure parameters applicable to RQL. RGOs are RBCs that may be considered in an FS to define the extent of contamination that must be remediated and help cost various alternatives. RGOs are media- and chemical-specific concentrations. The RGOs presented in this document are for protection of human health and may or may not be protective of ecological receptors. The process for calculating RGOs for this HHRA is a rearrangement of the cancer risk or non-cancer hazard equations, with the goal of obtaining the concentration that will produce a specific risk or hazard level. For example, the RGO for arsenic at the cancer risk level of 10^{-5} for the Security Guard/Maintenance Worker is the concentration of arsenic that produces a risk of 10^{-5} when using the exposure parameters specific to the Security Guard/Maintenance Worker receptor.

As discussed in Section 6.5.1, the cancer risk and non-cancer hazard are calculated as

$$\text{Risk} = (\text{Intake}) \times (\text{CSF}) \qquad \textbf{(6-26)}$$

and

$$\text{Hazard} = (\text{Intake}) / (\text{RfD}). \qquad \textbf{(6-27)}$$

The pathway-specific (e.g., soil ingestion) equations for intake are provided in Section 6.3.4. Note that all of the intake equations shown in Section 6.3.4 include a concentration term multiplied by several other exposure parameters.

To obtain the RGO for a specific risk level (e.g., 10^{-5}), the risk equation is rearranged so that the equation is solved for C, the concentration term. Similarly, to obtain the RGO for a specific hazard level (e.g., 1.0), the hazard equation is rearranged so that the equation is solved for the concentration term.

To demonstrate the soil ingestion pathway, note that by using the soil ingestion intake equation from Section 6.3.4 (Equation 6-12) and the general risk equation from Section 6.5.1, the risk from ingestion of soil is calculated as

$$\text{Risk}_{\text{ing(soil)}} = (C_s \times IR_s \times EF \times ED \times FI \times ET \times CF \times CSF) / (BW \times AT). \quad \textbf{(6-28)}$$

To obtain the RGO at the 10^{-5} risk level for the ingestion of soil, a value of 10^{-5} is substituted in the equation above for $\text{Risk}_{\text{ing(soil)}}$, and the equation is rearranged to solve for C_s. Thus, the general RGO equation at the 10^{-5} risk level for the ingestion of soil is calculated as

$$\text{RGO}_{\text{ing(soil)}} \text{ at } 10^{-5} = (10^{-5} \times BW \times AT) / (IR_s \times EF \times ED \times FI \times ET \times CF \times CSF). \quad \textbf{(6-29)}$$

A similar rearrangement of the ingestion of soil hazard equation is made, producing the general RGO equation at the 1.0 hazard level for this pathway/medium:

$$\text{RGO}_{\text{ing(soil)}} \text{ at } 1.0 = (1.0 \times BW \times AT \times RfD) / (IR_s \times EF \times ED \times FI \times ET \times CF). \quad \textbf{(6-30)}$$

Thus, to obtain the ingestion of soil RGO at the 10^{-5} risk level for the Security Guard/Maintenance Worker exposed to arsenic, the parameter values for the Security Guard/Maintenance Worker (from Table 6-6) and the chemical-specific oral CSF (from Table L-7) for arsenic are used:

$$\text{RGO}_{\text{ing(soil)}} \text{ at } 10^{-5} \text{ for arsenic} = [(10^{-5})(70)(25550)] / (0.0001)(250)(25)(1)(1)(0.042)(1.5)] = 458 \text{ mg/kg}.$$

In this example, the RGO calculated is 458 mg/kg, which will produce a soil ingestion risk of 10^{-5} for the Security Guard/Maintenance Worker exposed to arsenic in the surface soil. This example is based on the ingestion of soil; however, RGOs calculated for RQL include exposure by ingestion, dermal contact, and inhalation.

Note that if a calculated RGO is not physically possible (e.g., more than the pure chemical), then the RGO is adjusted accordingly. For example, if the calculated RGO is 5.5E+06 mg/kg, then the RGO is adjusted downward to 1.0E+06 mg/kg.

For this HHRA, RGOs are calculated for each exposure route (e.g., ingestion), as well as for the total chemical risk or hazard across all appropriate exposure routes. Carcinogenic RGOs are calculated and presented in this HHRA at a target risk (TR) level of 10^{-5}. To obtain the carcinogenic RGO at another risk level, one should adjust the RGO at 10^{-5} accordingly, taking care to check the resulting concentration against the physical limits discussed above (e.g., 1.0E+06 mg/kg). For example, to obtain the RGO at the 10^{-4} risk level, one should multiply the RGO at the 10^{-5} risk level by 10 (and then check the result to ensure that the concentration is physically possible). Non-carcinogenic RGOs are calculated and presented in this HHRA for a target hazard index (THI) level of 1.0. To find the non-carcinogenic RGO at another hazard level, one should adjust the RGO at the 1.0 hazard level accordingly, taking care to check the resulting concentration against the physical limits discussed above (e.g., 1.0E+06 mg/kg). For example, to obtain the RGO at the 3.0 hazard level, one should multiply the RGO at the 1.0 hazard level by 3 (and then check the result to ensure that the concentration is physically possible).

Exposure to multiple COCs may require downward adjustment of the TR and THI used to calculate final remedial levels. The TR and THI are dependent on several factors, including the number of carcinogenic and non-carcinogenic COCs and the target organs and toxic endpoints of these COCs. For example, if numerous (i.e., more than ten) non-carcinogenic COCs with similar toxic endpoints are present, it may be appropriate to use chemical-specific RGOs with a THI of 0.1 to account for exposure to multiple contaminants. The Security Guard/Maintenance Worker is the representative receptor for RQL. Nine COCs were identified for this receptor. All nine are carcinogenic (arsenic has both carcinogenic and non-carcinogenic effects, but its RGO is dominated by the carcinogenic effects). Of these nine COCs, one (arsenic) potentially produces respiratory system tumors, two are associated with stomach tumors [benz(*a*)anthracene and benzo(*a*)pyrene], three are associated with general tumors [benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, and indeno(1,2,3-*cd*)pyrene], one is associated with liver tumors (carbazole), one with carcinomas and malignant lymphoma (chrysene), and one with immunodepressive effects [dibenz(*a,h*)anthracene].

Surface soil RGOs are presented in Table 6-12 for all five receptors evaluated.

The following information concerning the RGOs for the nine Security Guard/Maintenance Worker surface soil COCs is noted:

The EPC for arsenic at RQL (15.3 mg/kg) is smaller than the most conservative (i.e., smallest) RGO across all pathways (the RGO based on a TR of 10^{-5} is 26 mg/kg). This EPC is also smaller than the arsenic surface soil background concentration for RVAAP (15.4 mg/kg).

The EPC for benzo(*k*)fluoranthene (107 mg/kg) is smaller than its most conservative RGO (the RGO for this COC, based on a TR of 10^{-5}, is 129 mg/kg).

- The EPC for carbazole (84.9 mg/kg) is smaller than its most conservative RGO (the RGO for this COC, based on a TR of 10^{-5}, is 608 mg/kg).

- The EPC for chrysene (185 mg/kg) is smaller than its most conservative RGO (the RGO for this COC, based on a TR of 10^{-5}, is 1287 mg/kg).

- The EPCs for the other five COCs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene] are all larger than their associated most conservative RGOs (based on a TR of 10^{-5}).

Finally, it is noted that the EPCs of the eight organic COCs are all highly influenced by the results from one particular sample (RQL-026). The largest concentrations for these eight organic COCs are all from sample RQL-026; the next largest concentrations are 1 to 2 orders of magnitude smaller than the results from RQL-026 and smaller than the RGOs for seven of the eight organic COCs [the next largest concentration for benzo(*a*)pyrene is slightly larger than its RGO]. Concentrations from this one sample inflate the EPCs for the eight organic COCs, causing them all to be COCs in this HHRA.

RGOs for groundwater, sediment, and surface water are provided in Tables 6-13, 6-14, and 6-15, respectively. RGOs are presented for all applicable receptors. The Security Guard/Maintenance Worker is not exposed to groundwater, sediment, or surface water, as discussed in Section 6.3.2.

Table 6-12. RGOs for Surface Soil Direct Contact COCs at the Ramsdell Quarry Landfill

COC	Ingestion RGO		Dermal RGO		Inhalation RGO		Total RGO[a]	
	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HI = 1.0	Risk = 10^{-5}
Hunter/Fisher								
Arsenic	1.5E+05	7.9E+03	8.2E+04	4.2E+03	--	1.0E+06	5.3E+04	2.8E+03
Chromium	1.0E+06	--	6.1E+05	--	1.0E+06	1.0E+06	4.4E+05	1.0E+06
2,6-Dinitrotoluene	5.1E+05	1.8E+04	8.2E+04	2.8E+03	--	--	7.1E+04	2.4E+03
Benz(a)anthracene	--	1.6E+04	--	2.0E+03	--	1.0E+06	--	1.8E+03
Benzo(a)pyrene	--	1.6E+03	--	2.0E+02	--	1.0E+06	--	1.8E+02
Benzo(b)fluoranthene	--	1.6E+04	--	2.0E+03	--	1.0E+06	--	1.8E+03
Benzo(k)fluoranthene	--	1.6E+05	--	2.0E+04	--	1.0E+06	--	1.8E+04
Carbazole	--	6.0E+05	--	9.6E+04	--	--	--	8.2E+04
Chrysene	--	1.0E+06	--	2.0E+05	--	1.0E+06	--	1.8E+05
Dibenz(a,h)anthracene	--	1.6E+03	--	2.0E+02	--	1.0E+06	--	1.8E+02
Indeno(1,2,3-cd)pyrene	--	1.6E+04	--	2.0E+03	--	1.0E+06	--	1.8E+03
National Guard Fire Suppression Worker								
Arsenic	3.1E+04	1.9E+03	1.7E+04	1.1E+03	--	4.0E+05	1.1E+04	6.8E+02
Chromium	3.1E+05	--	1.3E+05	--	1.0E+06	1.4E+05	8.9E+04	1.4E+05
2,6-Dinitrotoluene	1.0E+05	4.2E+03	1.7E+04	7.1E+02	--	--	1.5E+04	6.1E+02
Benz(a)anthracene	--	3.9E+03	--	5.1E+02	--	1.0E+06	--	4.5E+02
Benzo(a)pyrene	--	3.9E+02	--	5.1E+01	--	1.0E+06	--	4.5E+01
Benzo(b)fluoranthene	--	3.9E+03	--	5.1E+02	--	1.0E+06	--	4.5E+02
Benzo(k)fluoranthene	--	3.9E+04	--	5.1E+03	--	1.0E+06	--	4.5E+03
Carbazole	--	1.4E+05	--	2.4E+04	--	--	--	2.1E+04
Chrysene	--	3.9E+05	--	5.1E+04	--	1.0E+06	--	4.5E+04
Dibenz(a,h)anthracene	--	3.9E+02	--	5.1E+01	--	1.0E+06	--	4.5E+01
Indeno(1,2,3-cd)pyrene	--	3.9E+03	--	5.1E+02	--	1.0E+06	--	4.5E+02
National Guard Trainee								
Arsenic	2.0E+03	1.2E+02	6.6E+03	4.1E+02	--	4.6E+01	1.5E+03	3.1E+01
Chromium	2.0E+04	--	5.0E+04	--	7.0E+02	1.6E+01	6.7E+02	1.6E+01
2,6-Dinitrotoluene	6.6E+03	2.7E+02	6.6E+03	2.7E+02	--	--	3.3E+03	1.4E+02
Benz(a)anthracene	--	2.5E+02	--	2.0E+02	--	2.2E+03	--	1.0E+02
Benzo(a)pyrene	--	2.5E+01	--	2.0E+01	--	2.2E+02	--	1.0E+01
Benzo(b)fluoranthene	--	2.5E+02	--	2.0E+02	--	2.2E+03	--	1.0E+02
Benzo(k)fluoranthene	--	2.5E+03	--	2.0E+03	--	2.2E+04	--	1.0E+03
Carbazole	--	9.2E+03	--	9.3E+03	--	--	--	4.6E+03
Chrysene	--	2.5E+04	--	2.0E+04	--	2.2E+05	--	1.0E+04
Dibenz(a,h)anthracene	--	2.5E+01	--	2.0E+01	--	2.2E+02	--	1.0E+01
Indeno(1,2,3-cd)pyrene	--	2.5E+02	--	2.0E+02	--	2.2E+03	--	1.0E+02

Table 6-12. RGOs for Surface Soil Direct Contact COCs at the Ramsdell Quarry Landfill (continued)

COC	Ingestion RGO		Dermal RGO		Inhalation RGO		Total RGO[a]	
	HQ = 1.0	**Risk = 10^{-5}**	**HQ = 1.0**	**Risk = 10^{-5}**	**HQ = 1.0**	**Risk = 10^{-5}**	**HI = 1.0**	**Risk = 10^{-5}**
Resident Farmer Adult								
Arsenic	2.2E+02	1.1E+01	3.2E+02	1.7E+01	--	5.2E+03	1.3E+02	6.7E+00
Chromium	2.2E+03	--	2.4E+03	--	9.6E+04	1.9E+03	1.1E+03	1.9E+03
2,6-Dinitrotoluene	7.3E+02	2.5E+01	3.2E+02	1.1E+01	--	--	2.2E+02	7.6E+00
Benz(a)anthracene	--	2.3E+01	--	7.9E+00	--	2.5E+05	--	5.9E+00
Benzo(a)pyrene	--	2.3E+00	--	7.9E-01	--	2.5E+04	--	5.9E-01
Benzo(b)fluoranthene	--	2.3E+01	--	7.9E+00	--	2.5E+05	--	5.9E+00
Benzo(k)fluoranthene	--	2.3E+02	--	7.9E+01	--	1.0E+06	--	5.9E+01
Carbazole	--	8.5E+02	--	3.7E+02	--	--	--	2.6E+02
Chrysene	--	2.3E+03	--	7.9E+02	--	1.0E+06	--	5.9E+02
Dibenz(a,h)anthracene	--	2.3E+00	--	7.9E-01	--	2.5E+04	--	5.9E-01
Indeno(1,2,3-cd)pyrene	--	2.3E+01	--	7.9E+00	--	2.5E+05	--	5.9E+00
Resident Farmer Child								
Arsenic	2.3E+01	6.1E+00	3.6E+02	9.2E+01	--	1.1E+04	2.2E+01	5.7E+00
Chromium	2.3E+02	--	2.7E+03	--	4.1E+04	4.0E+03	2.1E+02	4.0E+03
2,6-Dinitrotoluene	7.8E+01	1.3E+01	3.6E+02	6.1E+01	--	--	6.4E+01	1.1E+01
Benz(a)anthracene	--	1.3E+01	--	4.4E+01	--	5.4E+05	--	9.7E+00
Benzo(a)pyrene	--	1.3E+00	--	4.4E+00	--	5.4E+04	--	9.7E-01
Benzo(*b*)fluoranthene	--	1.3E+01	--	4.4E+01	--	5.4E+05	--	9.7E+00
Benzo(*k*)fluoranthene	--	1.3E+02	--	4.4E+02	--	1.0E+06	--	9.7E+01
Carbazole	--	4.6E+02	--	2.1E+03	--	--	--	3.7E+02
Chrysene	--	1.3E+03	--	4.4E+03	--	1.0E+06	--	9.7E+02
Dibenz(*a,h*)anthracene	--	1.3E+00	--	4.4E+00	--	5.4E+04	--	9.7E-01
Indeno(*1,2,3-cd*)pyrene	--	1.3E+01	--	4.4E+01	--	5.4E+05	--	9.7E+00
Security Guard/Maintenance Worker								
Arsenic	7.4E+03	4.6E+02	4.4E+02	2.8E+01	--	2.1E+05	4.2E+02	2.6E+01
Chromium	7.4E+04	--	3.3E+03	--	1.0E+06	7.6E+04	3.2E+03	7.6E+04
2,6-Dinitrotoluene	2.5E+04	1.0E+03	4.4E+02	1.8E+01	--	--	4.3E+02	1.8E+01
Benz(*a*)anthracene	--	9.4E+02	--	1.3E+01	--	1.0E+06	--	1.3E+01
Benzo(*a*)pyrene	--	9.4E+01	--	1.3E+00	--	1.0E+06	--	1.3E+00
Benzo(*b*)fluoranthene	--	9.4E+02	--	1.3E+01	--	1.0E+06	--	1.3E+01
Benzo(*k*)fluoranthene	--	9.4E+03	--	1.3E+02	--	1.0E+06	--	1.3E+02
Carbazole	--	3.4E+04	--	6.2E+02	--	--	--	6.1E+02
Chrysene	--	9.4E+04	--	1.3E+03	--	1.0E+06	--	1.3E+03
Dibenz(*a,h*)anthracene	--	9.4E+01	--	1.3E+00	--	1.0E+06	--	1.3E+00
Indeno(*1,2,3-cd*)pyrene	--	9.4E+02	--	1.3E+01	--	1.0E+06	--	1.3E+01

[a] Total RGO is the RGO across all pathways (ingestion, dermal, and inhalation). All RGOs are in mg/kg.
COC = Chemical of concern.
HI = Hazard index.
HQ = Hazard quotient.
RGO = Remedial goal option.
-- = No RGO could be quantified based on lack of approved toxicity value.

Table 6-13. RGOs for Groundwater Direct Contact COCs at the Ramsdell Quarry Landfill

COC	**Ingestion RGO**		**Dermal RGO**		**Inhalation RGO**		**Total RGO**[a]	
	HQ = 1.0	**Risk = 10^{-5}**	**HQ = 1.0**	**Risk = 10^{-5}**	**HQ = 1.0**	**Risk = 10^{-5}**	**HI = 1.0**	**Risk = 10^{-5}**
National Guard Trainee								
Arsenic	9.8E-02	6.1E-03	2.1E+01	1.3E+00	--	--	9.8E-02	6.1E-03
Manganese	1.5E+01	--	1.9E+02	--	--	--	1.4E+01	--
Resident Farmer Adult								
Arsenic	1.1E-02	5.7E-04	2.3E+00	1.2E-01	--	--	1.1E-02	5.7E-04
Manganese	1.7E+00	--	2.2E+01	--	--	--	1.6E+00	--
Resident Farmer Child								
Arsenic	3.1E-03	8.1E-04	1.1E+00	2.9E-01	--	--	3.1E-03	8.1E-04
Manganese	4.8E-01	--	1.0E+01	--	--	--	4.6E-01	--

[a] Total RGO is the RGO across all pathways (ingestion, dermal, and inhalation). All RGOs are in mg/L.

COC = Chemical of concern.

RGO = Remedial goal option.

HI = Hazard index.

-- = NO RGO could be quantified based on lack of approved toxicity value.

HQ = Hazard quotient.

Table 6-14. RGOs for Sediment Direct Contact COCs at the Ramsdell Quarry Landfill

COC	Ingestion RGO		Dermal RGO		Inhalation RGO		Total RGO[a]	
	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HI = 1.0	Risk = 10^{-5}
Hunter/Fisher								
Arsenic	1.5E+05	7.9E+03	8.2E+04	4.2E+03	--	1.0E+06	5.3E+04	2.8E+03
Chromium	1.0E+06	--	6.1E+05	--	1.0E+06	1.0E+06	4.4E+05	1.0E+06
Manganese	1.0E+06	--	1.0E+06	--	1.0E+06	--	1.0E+06	--
Benzo(*a*)pyrene	--	1.6E+03	--	2.0E+02	--	1.0E+06	--	1.8E+02
National Guard Fire Suppression Worker								
Arsenic	3.1E+04	1.9E+03	1.7E+04	1.1E+03	--	4.0E+05	1.1E+04	6.8E+02
Chromium	3.1E+05	--	1.3E+05	--	1.0E+06	1.4E+05	8.9E+04	1.4E+05
Manganese	1.0E+06	--	1.0E+06	--	1.0E+06	--	1.0E+06	--
Benzo(*a*)pyrene	--	3.9E+02	--	5.1E+01	--	1.0E+06	--	4.5E+01
National Guard Trainee								
Arsenic	2.0E+03	1.2E+02	6.6E+03	4.1E+02	--	4.6E+01	1.5E+03	3.1E+01
Chromium	2.0E+04	--	5.0E+04	--	7.0E+02	1.6E+01	6.7E+02	1.6E+01
Manganese	3.0E+05	--	1.0E+06	--	3.5E+02	--	3.5E+02	--
Benzo(*a*)pyrene	--	2.5E+01	--	2.0E+01	--	2.2E+02	--	1.0E+01
Resident Farmer Adult								
Arsenic	2.2E+02	1.1E+01	3.2E+02	1.7E+01	--	5.2E+03	1.3E+02	6.7E+00
Chromium	2.2E+03	--	2.4E+03	--	9.6E+04	1.9E+03	1.1E+03	1.9E+03
Manganese	3.4E+04	--	5.9E+04	--	4.8E+04	--	1.5E+04	--
Benzo(*a*)pyrene	--	2.3E+00	--	7.9E-01	--	2.5E+04	--	5.9E-01
Resident Farmer Child								
Arsenic	2.3E+01	6.1E+00	3.6E+02	9.2E+01	--	1.1E+04	2.2E+01	5.7E+00
Chromium	2.3E+02	--	2.7E+03	--	4.1E+04	4.0E+03	2.1E+02	4.0E+03
Manganese	3.6E+03	--	6.5E+04	--	2.1E+04	--	2.9E+03	--
Benzo(*a*)pyrene	--	1.3E+00	--	4.4E+00	--	5.4E+04	--	9.7E-01

[a] Total RGO is the RGO across all pathways (ingestion, dermal, and inhalation). All RGOs are in mg/kg.

COC = Chemical of concern.

HQ = Hazard quotient.

HI = Hazard index.

-- = No RGO could be quantified on lack of approved toxicity value.

Table 6-15. RGOs for Surface Water Direct Contact COCs at the Ramsdell Quarry Landfill

COC	Ingestion RGO		Dermal RGO		Inhalation RGO		Total RGO[a]	
	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HQ = 1.0	Risk = 10^{-5}	HI = 1.0	Risk = 10^{-5}
Hunter/Fisher								
Arsenic	7.7E+01	4.0E+00	6.4E+01	3.3E+00	N/A	N/A	3.5E+01	1.8E+00
Manganese	1.2E+04	--	5.9E+02	--	N/A	N/A	5.6E+02	--
Aldrin	7.7E+00	3.5E-01	2.6E-02	1.2E-03	N/A	N/A	2.6E-02	1.2E-03
National Guard Fire Suppression Worker								
Arsenic	5.1E+00	3.2E-01	2.0E+01	1.2E+00	N/A	N/A	4.1E+00	2.5E-01
Manganese	7.8E+02	--	1.9E+02	--	N/A	N/A	1.5E+02	--
Aldrin	5.1E-01	2.8E-02	8.3E-03	4.6E-04	N/A	N/A	8.2E-03	4.5E-04
National Guard Trainee								
Arsenic	2.0E+00	1.2E-01	1.3E+00	8.0E-02	N/A	N/A	7.8E-01	4.8E-02
Manganese	3.0E+02	--	1.2E+01	--	N/A	N/A	1.1E+01	--
Aldrin	2.0E-01	1.1E-02	5.3E-04	2.9E-05	N/A	N/A	5.3E-04	2.9E-05
Resident Farmer Adult								
Arsenic	2.2E-01	1.1E-02	8.0E-01	4.1E-02	N/A	N/A	1.7E-01	8.9E-03
Manganese	3.4E+01	--	7.4E+00	--	N/A	N/A	6.0E+00	--
Aldrin	2.2E-02	1.0E-03	3.3E-04	1.5E-05	N/A	N/A	3.2E-04	1.5E-05
Resident Farmer Child								
Arsenic	4.7E-02	1.2E-02	4.4E-01	1.1E-01	N/A	N/A	4.2E-02	1.1E-02
Manganese	7.2E+00	--	4.1E+00	--	N/A	N/A	2.6E+00	--
Aldrin	4.7E-03	1.1E-03	1.8E-04	4.2E-05	N/A	N/A	1.8E-04	4.0E-05

[a] Total RGO is the RGO across all pathways (ingestion, dermal, and inhalation). All RGOs are in mg/L.
COC = Chemical of concern.
HI = Hazard index.
HQ = Hazard quotient.
N/A = Not applicable (risk-based RGOs for inhalation are only quantified for volatile organic compounds).
RGO = Remedial goal option.
-- = No RGO could be quantified based on lack of approved toxicity value.

6.8 SUMMARY AND CONCLUSIONS

This HHRA was conducted to evaluate risks and hazards associated with contaminated media at the RVAAP RQL AOC. Risks and hazards were estimated for one representative receptor (Security Guard/Maintenance Worker) exposed to one medium (surface soil, from a depth interval of 0 to 1 ft bgs). Risks and hazards were also calculated for potential exposure to surface soil, groundwater, sediment, and surface water by four additional receptors [National Guard Trainee, Fire/Dust Suppression Worker, Hunter/Fisher, and Resident Subsistence Farmer (adult and child)]. The following steps were used to generate conclusions regarding human health risks and hazards associated with contaminated surface soil at RQL:

- identification of COPCs,
- calculation of risks and hazards,
- identification of COCs, and
- calculation of RGOs.

Surface soil risks and hazards were evaluated and RGOs calculated for the Security Guard/Maintenance Worker as the representative receptor at RQL. Results are summarized below.

One metal (arsenic), seven PAHs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and one SVOC (carbazole) were identified as COCs in surface soil for the Security Guard/Maintenance Worker at RQL.

Risk-based RGOs were computed for all nine COCs at a TR of 10^{-5} and a THI of 1. The EPCs used in this HHRA for arsenic (15.3 mg/kg), benzo(*k*)fluoranthene (107 mg/kg), chrysene (185 mg/kg), and carbazole (84.9 mg/kg) were all smaller than their associated most conservative risk-based RGO (26; 129; 1,287; and 608 mg/kg, respectively, based on a TR of 10^{-5}). The EPC for arsenic (15.3 mg/kg) was also smaller than the surface soil background concentration for RVAAP (15.4 mg/kg). Surface soil EPCs were highly influenced by the results from one particular sample (RQL-026), as the MDCs for all eight organic COCs came from this one sample. For these eight organic COCs, the only sample location other than RQL-026 with a detected concentration larger than an RGO is RQL-025, with benzo(*a*)pyrene detected at 6.8 mg/kg (above its RGO of 1.29 mg/kg).

While a Land Use Plan has been drafted for RTLS [as summarized in the FWHHRAM (USACE 2004b)], and OHARNG will control the property, there is uncertainty in the details of the future land use (e.g., if the perimeter fence is not maintained, then a trespasser could enter the property or if hunting restrictions are relaxed, then a hunter could utilize the site). To address this uncertainty, additional receptors (e.g., Hunter/Fisher, National Guard Trainee, and Fire/Dust Suppression Worker) are included in the risk assessment. There is little to no uncertainty associated with the assumption that RVAAP will not be released for residential use; however, a Resident Subsistence Farmer receptor was evaluated to provide a baseline scenario to evaluate unrestricted release.

Results are presented for all exposure scenarios, pathways, and media in Appendix L. Risk characterization results are summarized in Table 6-16 for all receptors.

Table 6-16. Summary of Human Health Risks and Hazards at Ramsdell Quarry

Receptor	Total HI	Total ILCR
Groundwater		
National Guard Trainee	0.51	1.1E-05
Resident Subsistence Farmer – Adult	4.6	1.2E-04
Resident Subsistence Farmer – Child	16	8.4E-05
Surface Soil[a]		
Security Guard/Maintenance Worker	0.23	2.1E-03
National Guard Trainee	0.53	3.0E-04
Fire/Dust Suppression Worker	0.0074	6.1E-05
Recreational Hunter/Fisher	0.0015	1.5E-05
Resident Subsistence Farmer – Adult	0.54	4.6E-03
Resident Subsistence Farmer – Child	2.4	2.8E-03
Agricultural Foodstuffs[b]		
Resident Subsistence Farmer – Adult	65	4.1E-01
Resident Subsistence Farmer – Child	300	4.6E-01
Venison		
Resident Subsistence Farmer – Adult	0.00045	1.0E-06
Resident Subsistence Farmer – Child	0.0021	9.4E-07
Sediment		
National Guard Trainee	6.9	3.0E-05
Fire/Dust Suppression Worker	0.0060	5.5E-07
Recreational Hunter/Fisher	0.0011	1.4E-07

Table 6-16. Summary of Human Health Risks and Hazards at Ramsdell Quarry (continued)

Receptor	Total HI	Total ILCR
Resident Subsistence Farmer – Adult	0.51	5.4E-05
Resident Subsistence Farmer – Child	3.0	6.1E-05
Surface Water		
National Guard Trainee	0.61	8.8E-06
Fire/Dust Suppression Worker	0.051	1.1E-06
Recreational Hunter/Fisher	0.012	2.2E-07
Resident Subsistence Farmer – Adult	1.3	3.3E-05
Resident Subsistence Farmer – Child	3.3	2.3E-05
Waterfowl		
Recreational Hunter/Fisher	9.0	8.9E-04

[a] Surface soil defined as 0 to 1 ft for all receptors because shallow bedrock at the Ramsdell Quarry Landfill precludes deeper surface soil.

[b] Agricultural foodstuffs include milk, beef, and vegetables.

HI = Hazard index.

ILCR = Incremental lifetime cancer risk.

7.0 SCREENING ECOLOGICAL RISK ASSESSMENT

An ERA defines the likelihood of harmful effects on plants and animals as a result of exposure to chemical constituents. There are two types of ERAs: screening and baseline. A screening ERA (SERA) depends on available site data and is conservative in all regards. A baseline ERA (BERA) requires even more site-specific exposure and effects information, including such measurements as body burden measurements and bioassays, and often uses less conservative assumptions. A SERA or equivalent is needed to evaluate the possible risk to plants and wildlife from current and future exposure to contamination at RQL. The need for and nature of a BERA will be assessed following completion of the SERA.

The initial regulatory guidance for an ERA is contained in EPA's *Risk Assessment Guidance for Superfund (RAGS), Volume II, Environmental Evaluation Manual* (EPA 1989a) and in a subsequent document (EPA 1991a). Further discussion on the scientific basis for assessing ecological effects and risk is presented in *Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference Document* (EPA 1989c). Other early 1990s guidance is provided in the *Framework for Ecological Risk Assessment* (EPA 1992a). A second generation of guidance consists of the *Procedural Guidance for Ecological Risk Assessments at U.S. Army Exposure Units* (Wentsel et al. 1994) and in its replacement, the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* (Wentsel et al. 1996). In addition, the more recently published *Ecological Risk Assessment Guidance* (EPA 1997a, 1998) supersedes *RAGS, Volume II* (EPA 1989a). This latter guidance makes the distinction between the interrelated roles of screening and baseline ERAs. Briefly, SERAs utilize conservative assumptions for exposures and effects, while a BERA means increasingly unit-specific, more realistic (and generally less conservative) exposures and effects. More recently, published EPA guidance (EPA 1997a) was used because it provided the clearest information on preliminary or screening ERAs. The Army also has the RVAAP Facility-wide ERA Work Plan (USACE 2003a) to guide the work at RQL. Additionally, Ohio EPA has guidance, and that too is being used, especially for the hierarchy for ecological screening values (ESVs) (Ohio EPA 2003). And the work here covers Steps 1 and 2. Ohio EPA guidance identifies four levels of ERA: Level I Scoping, Level II Screening, Level III Baseline, and Level IV Field Baseline. This SERA for RQL includes the equivalent of Ohio EPA's Level I Scoping and Level II Screening ERAs.

These documents discuss an overall approach to considering ecological effects and to identifying sources of information necessary to perform ERAs. However, they do not provide all the details. Thus, professional knowledge and experience are important in ERAs to compensate for this lack of specific guidance and established methods. This professional experience comes from a team of risk scientists, who are representatives from RVAAP, USACE, Ohio EPA, and SAIC.

The following sections present the scope and objectives (Section 7.1); the procedural framework (Section 7.2); and the four steps to complete the screening work, hereafter referred to as the SERA, with emphasis on problem formulation (Section 7.3). The results are presented in Section 7.4. Finally, there is a recommendations section (Section 7.5) and a summary (Section 7.6).

7.1 SCOPE AND OBJECTIVES

The scope of the SERA is to characterize, in a preliminary way, the risk to plant and animal populations at RQL, including its aquatic environment, from analytes that are present in the surface soil, sediment, and surface water. This is done for current conditions. Unlike the HHRA, which focuses on individuals, the SERA focuses on generic groups of organisms. In the SERA process, individuals are addressed only if they are protected under the Endangered Species Act (ESA).

The SERA used site-specific analyte concentration data for surface soil, sediment, and surface water from various geographical parts of RQL. Risks to ecological receptors were evaluated by performing a multi-step screening process in which, after each step, the detected analytes in the media were either deemed to pose negligible risk and eliminated from further consideration or carried forward to the next step in the screening process to a final conclusion of being a contaminant of potential ecological concern (COPEC). COPECs are analytes whose concentrations are great enough to pose potential adverse effects to ecological receptors. The screening steps are described in detail in Section 7.3.3. COPECs are usually the starting point for more definitive BERAs.

The objective of the SERA was to identify whether any of the detected analytes in surface soil, sediment, and surface water at RQL posed sufficient potential risk to ecological receptors to warrant the analytes being classified as COPECs. This was done for soil, sediment, and surface water and generic receptors that would be exposed to these media. Groundwater is not a medium of concern for ecological receptors. However, any groundwater that may enter the seasonal pond during the wet season is treated as surface water once it enters the water body. In addition, the section contains an ecological CSM, selection of receptor, definition of exposure pathways, and selection of assessment endpoints and measures.

7.2 PROCEDURAL FRAMEWORK

According to the *Framework for Ecological Risk Assessment* (EPA 1992a), the SERA process consists of three interrelated phases: problem formulation, analysis (composed of exposure assessment and ecological effects assessment), and risk characterization. In conducting the SERA for RQL, these three phases were partially completed by performing four interrelated steps. Each has the following parts.

- **Problem Formulation:** Problem formulation establishes the goals, breadth, and focus of the SERA and provides a characterization (screening step) of chemical stressors (chemicals that restrict growth and reproduction or otherwise disturb the balance of ecological populations and systems) present in the various habitats at the site. The problem formulation step also includes a preliminary characterization of the components, especially the ecological receptor, in the ecosystem likely to be at risk. It can also include the selection of assessment and measurement endpoints as a basis for developing a conceptual model of stressors, components, and effects (Section 7.3).

- **Exposure Assessment:** Exposure assessment defines and evaluates the concentrations of the chemical stressors. It also describes the ecological receptors began to define the route, magnitude, frequency, duration, and spatial pattern of the exposure of each receptor population to a chemical stressor (Section 7.4).

- **Effects Assessment:** Effects assessment evaluates the ecological response to chemical stressors in terms of the selected assessment and measurement endpoints. The effects assessment results in a profile of the ecological response of populations of plants and animals to the chemical concentrations or doses and to other types and units of stress to which they are exposed. Data from both field observations and controlled laboratory studies are used to assess ecological effects (Section 7.4).

- **Risk Characterization:** Risk characterization integrates exposure and effects or the response to chemical stressors on ecological receptors using HQs, which are ratios of exposure concentrations to concentrations associated with an effect. The results are used to define the risk from contamination at RQL. In the present scope, it is an exceedance of an ESV that is an equivalent of being in harm's way.

The SERA is organized by the four interrelated steps of the EPA framework. Section 7.3 covers problem formulation. Section 7.4 details results and discussion from an exposure/effects/risk viewpoint. Section 7.5 provides the recommendations regarding potential next steps. Finally, Section 7.6 provides the summary.

7.3 PROBLEM FORMULATION

The first step of EPA's approach to the SERA process, problem formulation (data collection and evaluation), includes:

- descriptions of habitats, biota, and threatened and endangered (T&E) (Section 7.3.1);
- selection of EUs (Section 7.3.2); and
- identification of COPECs (Section 7.3.3).

7.3.1 Description of Habitats, Biota, Threatened and Endangered Species, and Populations

This section provides a description of the ecological resources at RQL. Habitats and communities are discussed in Section 7.3.1.1. Resource management topics are presented in Sections 7.3.1.2 and 7.3.1.3. Animals are discussed in Section 7.3.1.4. Aquatic habitats are discussed in Section 7.3.1.5, and protected species are discussed in Section 7.3.1.6. All of this information shows that Level I in the Ohio EPA guidance is met. There are ecological resources present in the form of vegetation and animal life in both terrestrial and aquatic ecosystems. Thus, Level II was justified.

7.3.1.1 Terrestrial habitats and plant communities

The RQL AOC occupies a total area of about 33.8 acres (Table 7-1). The RQL area includes forests and woodlands, shrublands, grasslands, wetlands, old railroad beds, paved and unpaved roads, and other unvegetated areas at the site. The vegetated areas provide habitat for the many plants and animals at Ravenna. Information on plant communities at RQL was gleaned from the *Plant Community Survey For The Ravenna Army Ammunition Plant* (SAIC 1999). The RVAAP plant community survey was based on a combination of color infrared and black-and-white aerial photogrammetry available from the mid-1990s and field surveys conducted in autumn 1998 and spring and summer 1999. An additional field survey of RQL was conducted in October 2003.

Table 7-1. Plant Communities and Other Habitat Recorded at the Ramsdell Quarry Landfill

Plant Community Type	Acres	% Area
Forest Formations		
Fagus grandifolia - *Acer saccharum* - (*Liriodendron tulipifera*) Forest Alliance	3.6	10.6
Quercus alba - (*Quercus rubra*, *Carya* spp.) Forest Alliance	3.2	9.4
Acer rubrum successional forest	0.8	2.4
Orchards	0.3	0.9
Shrubland Formations		
Dry mid-successional, temperate, cold-deciduous shrubland	8.7	25.8
Herbaceous Formations		
Maintained grassland	10.3	30.6
Typha spp.-(*Scirpus* spp.) Seasonally Flooded Herbaceous Alliance	4.6	13.6
Other Landscape Features		
Open Water	2.3	6.7
Total	33.8	100.0

Forest Formations

Forests at RVAAP correspond to plant communities with closed tree canopies. Forest formations occupy approximately 13,330 acres at RVAAP. Note that some areas at RVAAP contain plant communities dominated by tree species, but intermixed with patches of shrubs as a result of past disturbance. The following types of forest alliances occur at the RQL AOC.

Fagus grandifolia - *Acer saccharum* - (*Liriodendron tulipifera*) Forest Alliance

This forest alliance describes a diverse community common to mesic, gently sloping sites throughout the east-central United States and southern Canada. At RVAAP, many of the most mature upland stands correspond to this alliance. American beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) dominate the canopy. Other common trees include yellow-poplar (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), American basswood (*Tilia americana*), various hickories (*Carya* spp.), and occasionally white oak (*Quercus alba*). Shrub and herbaceous species are generally sparse, probably as a result of heavy browsing by deer. Spicebush (*Lindera benzoin*), American hornbeam (*Carpinus caroliniana*), and eastern hop-hornbeam (*Ostrya virginiana*) were frequently observed in the understory. Mayapple (*Podophyllum peltatum*) and New York fern (*Thelypteris noveboracensis*) were frequently observed in the herbaceous layer. This community is located along the northwestern and southern sides of RQL. This forest type makes up about 3.6 acres or 10.6% of the RQL AOC (Table 7-1).

Quercus alba - (*Quercus rubra*, *Carya* spp.) Forest Alliance

This alliance is the least abundant of the deciduous upland forest types found at RVAAP. It is found on well-drained sites often in gently sloping areas. Characteristic species include white oak (*Quercus alba*), northern red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), and bitternut hickory (*Carya cordiformis*). Less abundant species include sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), wild black cherry (*Prunus serotina*), and American beech (*Fagus grandifolia*). Understory species include American hornbeam (*Carpinus caroliniana*) and flowering dogwood (*Cornus florida*). The herbaceous layer is generally sparse. In some locations, stands of this forest type dominated by white oak appear to have been planted. These areas have become somewhat naturalized and were no longer considered plantations in this study. This forest alliance occurs along the western side of the RQL AOC. This forest type makes up about 3.2 acres or 9.4% of the RQL AOC (Table 7-1).

Acer rubrum Successional Forest

This transitional forest community is very common at RVAAP. It is characterized by a high abundance of red maple (*Acer rubrum*), often in nearly pure stands. Green ash (*Fraxinus pennsylvanica*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), and sugar maple (*Acer saccharum*) often are present, but they are never dominant. In some cases, the canopy is very dense and little to no ground cover is present. In other cases the canopy is somewhat open and old field species such as blackberry (*Rubus allegheniensis*), goldenrod (*Solidago* spp.), dogbane (*Apocynum cannabinum*), and self-heal or heal-all (*Prunella vulgaris*) form a dense herbaceous layer. In general, the stand age is fairly even. This forest type is located throughout Ravenna. At RQL, *Acer rubrum* successional forest occupies a small portion of the north-central side of the AOC; it makes up about 0.8 acre or 2.4% of the RQL AOC (Table 7-1).

Orchards and Groves (Fruit and Nut Trees)

This community describes old orchards, typically apple (*Malus sylvestris*), that have been unmaintained for at least several decades. Lack of maintenance has allowed colonization of these areas by shrubs, small trees, and often a thick herbaceous layer, but fruit trees generally still dominate the canopy. Orchards are a relatively minor component of the RVAAP forests. At RQL, there is a very small patch of remnant orchard in the north-central part of the AOC along Ramsdell Road, immediately north of the old quarry pit. This forest type makes up about 0.3 acre or 0.9% of the RQL AOC (Table 7-1).

Shrubland Formations

Shrubland formations at RVAAP correspond to plant communities where the dominant life form is shrub. The term shrub corresponds to both true shrub species and young tree species (seedlings and saplings). For example, successional areas at RVAAP that contain young trees or young trees mixed with shrubs were classified as shrubland if the majority of the vegetation did not exceed 20 ft in height. Note that many areas at RVAAP that were classified as shrubland are successional areas comprised mostly of young trees mixed with shrubs (i.e., mature old fields). Without disturbance, many of these areas will probably develop into young forest communities within approximately 5 to 15 years. The following shrubland formation occurs at the RQL AOC (Table 7-1).

Dry Mid-successional Cold-deciduous Shrubland

The dry mid-successional cold-deciduous shrubland community describes a plant grouping at RVAAP that is frequently encountered in previously disturbed areas (e.g., former agricultural fields) that have had sufficient recovery time for invasion by shrub species. This community is present throughout RVAAP covering large (> 10 acres) as well smaller areas (< 1 acre). It is characterized by shrub species covering more than 50% of the area with relatively few large trees (> 20 ft in height). Common shrub species include gray dogwood (*Cornus racemosa*), northern arrowwood (*Viburnum recognitum*), blackberry (*Rubus allegheniensis*), hawthorn (*Crataegus* spp.), and multiflora rose (*Rosa multiflora*). Typical pioneer tree species include red maple (*Acer rubrum*), wild black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), and black locust (*Robinia pseudoacacia*). Included in this community at RQL is a small white oak plantation. A dense herbaceous community is present with common species such as goldenrod (*Solidago* spp.), dogbane (*Apocynum cannabinum*), self-heal or heal-all (*Prunella vulgaris*), yarrow (*Achillea millefolium*), strawberry (*Fragaria virginiana*), black-eyed Susan (*Rudbeckia hirta*), sheep sorrel (*Rumex acetosella*), and fescue grasses (*Festuca* spp., mostly *Festuca arundinacea*). At RQL, this community occupies most of the eastern side of the AOC. This vegetation type makes up about 8.7 acres or 25.8% of the RQL AOC (Table 7-1).

Herbaceous Formations

Herbaceous formations at RVAAP correspond to plant communities where the dominant life form is herbaceous (non-woody). Herbaceous formations occupy approximately 3,400 acres at RVAAP. The following types of herbaceous vegetation formations occur at the RQL AOC.

Maintained Grassland

This community refers to areas at RVAAP that were seeded with grass in the past and are currently maintained in a grassland condition through periodic mowing. This community is generally not located near buildings and is not part of the lawns associated with landscaping around buildings. At RQL, this community type surrounds the east side of the quarry around the southern and western sides of the quarry.

The old landfill cap and surrounding area at RQL are included in this type. It covers about 10.3 acres or 30.6% of the AOC (Table 7-1).

Typha spp. - (_Scirpus_ spp. - _Juncus_ spp.) Seasonally Flooded Herbaceous Alliance

This shallow marsh alliance is characterized by cattails (*Typha* spp.), bulrushes (*Scirpus* spp.), rushes (*Juncus* spp.), giant bur-reed (*Sparganium eurycarpum*), big-leaved arrowhead (*Sagittaria latifolia*), duckweed (*Lemna* spp.), blue vervain (*Verbena hastata*), manna grass (*Glyceria* spp.), and water plantain (*Alisma plantago-aquatica*). Cattails do not dominate this alliance. Rather, cattails, bulrushes, and rushes share dominance in approximately equal proportions in this formation. At RQL, common reed, *Phragmites arundinacea*, an exotic, invasive pest plant dominates this vegetation type. Saturated or inundated conditions prevail during much of the growing season, but water depths generally do not exceed 6 to 12 in. This vegetation type occurs down inside the old quarry pit. It covers about 4.6 acres or 13.6% of the AOC (Table 7-1).

Other Landscape Features

Other landscape features at RQL include a shallow pond down inside the old quarry pit. The size and depth of this pond fluctuates seasonally and varies with rainfall patterns. It often dries up completely by late summer or fall. The pond usually covers about 2.3 acres or 6.7% of the AOC (Table 7-1).

7.3.1.2 Forestry resources and management

RQL lies just within the northern border of Forest Management Compartment 7 of the ten management compartments designated within the RVAAP. While each compartment is further subdivided into cutting units, the cutting unit boundaries reflect topographic features (e.g., creeks and roads) rather than forest types. Of Compartment 7's total 2,860 acres, 2,046 acres are in sawtimber (994 acres), poletimber (681 acres), and timber stands considered to be of adequate regeneration (371 acres). No specific timber stand improvement prescriptions are currently in place for Forest Management Compartment 7, although limited harvesting is scheduled as sawtimber clearing for powerline right-of-way maintenance. The timber harvest schedule for RVAAP forests shows Forest Management Compartment 7 being harvested during 2008 with an expected allowable harvest of over 600,000 board feet (Doyle Rule) (OHARNG 2001).

RQL supports 7.9 acres of forest, about 23% of this AOC's total area (SAIC 1999). The four forest types – American beech-sugar maple, white oak-hickory, red maple, and orchard – were described in the previous section on forest formations.

RQL was closed (OHARNG 2001) in 1990. The Operations Support Command/RVAAP is required to maintain the clay cap and prevent soil erosion by maintaining the grass cover (roughly 10 acres) and preventing the establishment of woody species. This is accomplished by annual mowing and reseeding as required. The grass cover was established in 1990 using a seed mix that consisted of orchard grass, perennial ryegrass, birdsfoot trefoil, alsike clover, redtop, and annual ryegrass (OHARNG 2001).

7.3.1.3 Special management considerations

Special Interest Areas and Sensitive Areas

The Ohio Department of Natural Resources (ODNR) and the U.S. Fish and Wildlife Service did not identify any sensitive habitats on or near RQL during their natural heritage data searches (OHARNG 2001). No Special Interest Areas have been designated within or include any portion of RQL

(OHARNG 2001, Morgan 2004). Special Interest Areas include communities that host state-listed species, are representative of historic ecosystems, or are otherwise noteworthy (OHARNG 2001).

RQL does fall within a small sensitive area as identified within the Forest Management Operations plan (Figure 13 – Special Management Consideration Areas for Forest Management Operations) (OHARNG 2001). This sensitive area designation is because of the wetlands present within this AOC (Morgan 2004).

Jurisdictional Wetlands

There have been two jurisdictional delineations performed in recent years to support National Environmental Policy Act (NEPA) requirements of specific project proposals. All of these maps and delineations are on file in the RTLS Environmental Office (OHARNG 2001). No wetland delineations have been performed on RVAAP (Morgan 2004). However, it is possible that jurisdictional wetlands would be found within the RQL AOC if a jurisdictional delineation were to be performed (Morgan 2004).

The Ohio rapid assessment method for wetlands (Ohio EPA 2001) was applied at RQL. Habitat sketches, the scoring boundary worksheet, narrative rating, and quantitative rating are found in Appendix M. The total score was 22.5, which is a rather low number for the wetland area formed in the quarry pit.

7.3.1.4 Animal populations

The plant communities at RVAAP provide diverse habitats that support many species of animals. Results of 1992 and 1993 ODNR biological surveys included 27 mammals, 154 birds, 12 reptiles, 19 amphibians, 47 fish (including 6 hybrids), 4 crayfish, 17 mussels and clams, 11 aquatic snails, 26 terrestrial snails, 37 damselflies and dragonflies, 58 butterflies, and 485 moths. Several game species, such as deer, are managed through hunts scheduled during the fall months (ODNR 1997).

The plant communities within the RQL AOC also provide varied habitats that support several species of animals. About 25% of the RQL AOC is covered by open shrubland habitat. Common bird species that could be expected to use this habitat include the song sparrow (*Melospiza melodia*), common yellowthroat (*Geothylpis trichas*), gray catbird (*Dumetella carolinensis*), rufous-sided towhee (*Pipilo erythrophthalmus*), American goldfinch (*Carduelis tristis*), and blue-winged warbler (*Vermivora pinus*). Common large mammals include white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and woodchuck (*Marmota monax*), while eastern cottontail (*Sylvilagus floridanus*), white-footed mouse (*Peromyscus leucopus*), and short-tailed shrew (*Blarina brevicauda*) are common small mammals (ODNR 1997).

Woodland bird species, such as the wood thrush (*Hylocichla mustlina*), are likely to be found within the beech-maple-yellow poplar stands along the northwestern and southern sides of the AOC and the oak-hickory stand along the western side. These woodlands and their edges likely provide habitat for species such as the red-eyed vireo (*Vireo olivaceous*), yellow-throated vireo (*Vireo flavifrons*), eastern wood-pewee (*Contopus virens*) and Acadian flycatcher (*Empidonax virescens*), in addition to permanent residents typified by the tufted titmouse (*Parus bicolor*), black-capped chickadee (*Parus atricapillus*), American crow (*Corvus brachyrhynchos*), bluejay (*Cyanocitta cristata*), and red-bellied (*Melanerpes carolinus*) and downy (*Picoides pubescens*) woodpeckers (ODNR 1997).

Aquatic habitats at RQL are limited by climatic conditions. A shallow pool forms in the pit during wet weather that supports several species of amphibians, notably salamanders and frogs.

7.3.1.5 Threatened and endangered species

The relative isolation and protection of habitat at RVAAP has created an important area of refuge for a number of plant and animal species considered rare by the state of Ohio. To date, 74 state-listed species are confirmed to be on the RVAAP property. None of these are known to exist within RQL (Morgan 2005). See Table 2-1 for a list of T&E species at RTLS/RVAAP.

Federal

There are no federally listed plants or animals currently known to occur at RVAAP. Site-wide bat surveys were performed in 1999 and 2004 (ODNR 1999, ES&I 2005). Bat species captured included little brown bats, big brown bats, northern long-eared bats, red bats, and hoary bats, and eastern pipistrelle. Although the federally listed endangered Indiana bat (Myotis sodalis) has been documented nearby, the Indiana bat was not identified during any surveys and does not occur on RVAAP or at RQL (OHARNG 2001).

Several species listed as under Federal Observation (formerly Federal Candidate Species, Category 2) occur on RVAAP. These species include the Cerulean Warbler (Dendroica cerulea), henslow's Sparrow (Ammodramus henslowii), and butternut trees (Juglans cinerea) (ODNR 1997). None of these species has been documented at RQL (Morgan 2005).

State

State-listed endangered species include six birds [American bittern (Botaurus lentiginosus) (migrant), Northern harrier (Circus cyaneus), Yellow-bellied Sapsucker (Sphyrapicus varius), Golden-winged warbler (Vermivora chrysoptera), Osprey (Pandion haliaetus) (migrant), and Trumpeter swan (Cygnus buccinator) (migrant)], a lamprey [Mountain Brook Lamprey (Ichthyomyzon greeleyi)], a butterfly [Graceful Underwing (Catocala gracilis)], two plants [Ovate Spikerush (Eleocharis ovata) (Blunt spike-rush) and Tufted Moisture-loving Moss (Philonotis fontana var. caespitosa)], and one mammal [Bobcat (Felis rufus)]. None of these species has been documented at RQL (Morgan 2005).

State-listed threatened species include five birds [Barn owl (Tyto alba), Dark-eyed junco (Junco hyemalis) (migrant), Hermit thrush (Catharus guttatus) (migrant), Least bittern (Ixobrychus exilis), and Least flycatcher (Empidonax minimus)], one insect [Psilotreta indecisa (caddisfly)], and two plants [Simple willow-herb (Epilobium strictum) and Woodland Horsetail (Equisetum sylvaticum)]. None of these species has been documented at RQL (Morgan 2005).

Portage County has more rare species, especially plants, than any other county in Ohio. This is reflected in the number of species occurring on RVAAP that are listed as State Potentially Threatened. These species include four tree species [Gray Birch (Betula populifolia), Butternut (Juglans cinerea), Arbor Vitae (Thuja occidentalis), and American Chestnut (Castanea dentate)], two woody species [Northern rose azalea (Rhododendron nudiflorum var. roseum) and Hobblebush (Viburnum alnifolium)], and seven herbaceous species [Pale sedge (Carex pallescens), Long Beech Fern (Phegopteris connectilis), Straw sedge (Carex straminea), Water avens (Geum rivale), Tall St. John's wort (Hypercium majus), Swamp oats (Sphenopholis pensylvanica), and Shining ladies'-tresses (Spiranthes lucida). None of these species has been documented at RQL (Morgan 2005).

Species that are state-listed as of Special Concern [listed by either Ohio Department of Wildlife (ODOW) or the Heritage Program (Heritage)] include 3 mammals [Pygmy shrew (Sorex hovi), Star-nosed mole (Condylura cristata), and Woodland jumping mouse (Napaeozapus insignis)], 11 birds [Sharp-shinned hawk (Accipiter striatus), Marsh wren (Cistothorus palustris), Henslow's sparrow (Ammodramus henslowii), Cerulean warbler (Dendroica cerulean), Prothonotary warbler (Protonotaria citrea), Bobolink

(Dolichonyx oryzivorus), Northern bobwhite (Colinus virginianus), Common moorhen (Gallinula chloropus), Great egret (Casmerodius albus), Sora (Porzana Carolina), and Virginia Rail (Rallus limicola)], 1 freshwater mussel [Creek heelsplitter (Lasmigona compressa)], 1 reptile [Eastern box turtle (Terrapene Carolina)], 1 amphibian [Four-toed Salamander (Hemidactylium scutatum)], and 3 insects [Stenonema ithica (mayfly), Apamea mixta (moth), and Brachylomia algens (moth)]. None of these species has been documented at RQL (Morgan 2005).

Species that are state-listed as Special Interest include 21 birds [Canada warbler (Wilsonia Canadensis), Little blue heron (Egretta caerula), Magnolia warbler (Dendroica magnolia), Northern waterthrush (Seiurus noveboracensis), Winter wren (Troglodytes troglodytes), Back throated blue warbler (Dendroica caerulescens), Brown creeper (Certhia Americana), Mourning warbler (Oporornis Philadelphia), Pine siskin (Carduelis pinus), Purple finch (Carpodacus purpureus), Red-breasted nuthatch (Sitta canadensis), Golden-crowned kinglet (Regulus satrapa), Blackburnian warbler (Dendroica fusca), Blue grosbeak (Guiraca caerulea), Common snipe (Gallinago gallinago), American wigeon (Anas Americana), Gadwall (Anas strepera), Green-winged teal (Anas crecca), Northern shoveler (Anas clypeata), Redhead duck (Aythya americana), and Ruddy duck (Oxyura jamaicensis)] and 1 plant [Pohlia elongata var. elongata (No Common Name, Bryophyte)]. None of these species has been documented at RQL (Morgan 2005).

Note that there are currently no federally listed species or critical habitat on the RTLS/RVAAP property. Thus, there are no known legally protected species to require special consideration.

7.3.2 Selection of Exposure Units

From the ecological assessment viewpoint, an EU is the area where ecological receptors potentially are exposed to the site constituents. Thus, the EU is defined on the basis of the historical use of various processes. Although some ecological receptors are likely to gather food, seek shelter, reproduce, and move around, spatial boundaries of the ecological EUs are the same as the spatial boundaries of aggregates defined for nature and extent, fate and transport, and the HHRA. These proposed EUs for RQL are as follows:

Terrestrial EU:

- Soil at Ramsdell Quarry Landfill.

Sediment EU:

- Pond at bottom of quarry.

Surface water EU:

- Pond at bottom of quarry.

The distinction between EUs is based on location and history of the units. Each of the EUs is spatially separated. The exact history of waste applications and spills at each EU is uncertain. This uncertainty regarding waste applications and spills provides further justification for the distinction between the EUs.

7.3.3 Identification of Constituents of Potential Ecological Concern

COPECs were identified by using methods described for Level II Screening in Ohio EPA's *Ecological Risk Assessment Guidance Document* (Ohio EPA 2003). Identification of COPECs entailed a multi-step process that began with the detected chemicals of interest (COIs) that were identified in the Level I Scoping and included a data evaluation, media evaluation, and media screening as part of the Level II Screen. These three processes are described below in sections 7.3.3.1, 7.3.3.2, and 7.3.3.3, respectively.

7.3.3.1 Data evaluation

The data evaluation of COIs entailed two components: a frequency of detection analysis and an evaluation of common laboratory contaminants. The purpose of the frequency of detection analysis was to eliminate from further consideration any COIs that were detected in 5% or less of the samples for a given medium. However, COIs that were present in multiple media, or deemed to be persistent, bioaccumulative, and toxic (PBT) were not eliminated, even if they failed the frequency of detection evaluation. PBT compounds included four inorganics (cadmium, lead, mercury, and zinc) because of their bioaccumulative potential, as well as any organic compound whose log octanol-water (K_{ow}) partitioning coefficient was greater than or equal to 3.0. Appendix Table M-1 lists the Log K_{ow} values for organic compounds.

Common laboratory contaminants included acetone, 2-butanone (methyl ethyl ketone), carbon disulfide, methylene chloride, toluene, and phthalate esters. If blanks contained detectable concentrations of these contaminants, then the sample results were considered positive results if the sample concentrations exceeded 10-fold the maximum amount detected in any blank.

7.3.3.2 Media evaluation

The media evaluation was performed after the frequency of detection and common laboratory contaminant evaluation, using the COIs that were not eliminated during those two steps. The purpose of the media evaluation was to determine whether SRCs have impacted media associated with the site. The evaluation methods were media-specific, and included comparison against background concentrations for all media and comparison against Ohio-specific sediment reference values (SRVs) for sediment. Ohio EPA (2003) specifies SRVs to be used for sediments from lentic (standing water) surface water bodies. Although water in RQL is lentic (not flowing), Ohio-specific SRVs were used with the approval of Ohio EPA for acceptable background values whenever available. The SRVs were derived by Ohio EPA (2003) to be used in lieu of or in addition to on-site sediment background values.

Next, MDCs of COIs in soil, sediment, and surface water were compared to selected background concentrations and eliminated from further consideration in the Level II Screen if the maximum concentrations were less than background values (or SRVs) and the COIs were not PBT compounds. If the MDCs of COIs exceeded background values or SRVs, and/or the COIs were PBT compounds, the COIs were deemed COPECs and were carried forward to the media screening step.

7.3.3.3 Media screening

The media-screening step proceeded after the data/media evaluations, using the inputted COPECs identified in those two steps, assuming a decision was made to proceed with the ERA process instead of selecting a removal action. The media screening process was media-specific (Ohio EPA 2003). For example, MDCs of the COPECs for surface soil and sediment were compared against media-specific ESVs recommended by Ohio EPA (2003). The ESVs are conservative toxicological benchmarks that represent concentrations, which if not exceeded, should cause no adverse effects to most ecological receptors exposed to the media. For surface water, average concentrations of COPECs that were identified during the data and media evaluations were compared against OAC WQC pursuant to OAC 3745-1 and an updated summary (per December 30, 2002) of criteria posted on the Ohio EPA website (http://www.epa.state.oh.us/dws/wqc/criteria.html). Each COPEC was considered separately. The soil and sediment ESVs, as well as the OAC WQC that were used for the media screening, are presented in Appendix Tables M-2 through M-4, respectively.

For the media screening, any inputted soil or sediment COPEC that was not a PBT compound and whose MDC did not exceed the ESV was not retained as a COPEC and was eliminated from further consideration in the Level II Screen. For surface water, any inputted COPEC that was not a PBT compound and whose average concentration did not exceed the OAC WQC was also eliminated from further consideration. If no COPECs were retained in any medium, that medium was eliminated from further ecological risk evaluation (Ohio EPA 2003). However, any inputted COPECs whose concentrations exceeded ESVs or OAC WQC, or that did not have ESVs or OAC WQC, and/or were PBT compounds, were retained as COPECs.

The sources and screening hierarchy of soil and sediment screening benchmarks were specified by Ohio EPA (2003) as follows.

Soil Screening Hierarchy

For soils, the MDC of each COPEC was compared to soil screening values. The hierarchy of sources of soil screening values, in order of preference, (Ohio EPA 2003) was as follows:

- Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones, 1997a. *Preliminary Remediation Goals for Ecological Endpoints,* ES/ER/TM-162/R2.

- Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997b. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*, ES/ER/TM-126/R2.

- Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997c. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*, ES/ER/TM-85/R3.

- The fourth stated source is *Ecological Data Quality Levels (EDQL), U. S. EPA, Region 5, Final Technical Approach for Developing EDQLs for RCRA Appendix IX Constituents and Other Significant Contaminants of Concern, 1999* (EPA 1999a). However, that reference has been superceded by *Region 5 Corrective Action, Ecological Screening Levels (2003)* (EPA 2003a).

Sediment Screening Hierarchy

For sediments, the stream must have an Aquatic Life Habitat Use Designation. If there is full attainment of biological criteria for that designation, sediment is dismissed from further evaluation. If there is not full attainment of biological criteria, the MDCs of COPECs are to be compared to sediment screening values. The hierarchy for sediment screening values (Ohio EPA 2003), in order of preference, was as follows:

- Consensus-based threshold effects concentrations values (MacDonald, Ingersoll, and Berger 2000).

- *Ecological Data Quality Levels (EDQL), U.S. EPA, Region 5, Final Technical Approach for Developing EDQLs for RCRA Appendix IX Constituents and Other Significant Contaminants of*

Concern, 1999 (EPA 1999a). However, this reference has been superceded by *Region 5 Corrective Action, Ecological Screening Levels (2003)* (EPA 2003a).

Surface Water Hierarchy

For surface water, one uses the chemical criteria pursuant to OAC 3745-1 for the Erie Ontario Lake Plain ecoregion (Ohio EPA 2002). The guidance (Ohio EPA 2003) specifies that samples averaged over a 30-day period are to be compared to "outside mixing zone average" criteria for human health, aquatic life, and wildlife. Single ambient samples are not to exceed the "outside mixing zone maximum" criteria, but because multiple surface water samples were available, the "outside mixing zone average" criteria were used for the Level II Screen. In addition, biological criteria for the aquatic life habitat designation, warm water habitat, pursuant to AOC 3745-1-07 for the Lake Erie basin ecoregion, must be met.

7.4 RESULTS AND DISCUSSION

This section presents the findings or results of the data and media evaluation and comparisons of various media concentrations (e.g., maximum or average concentrations) and various effects measurements (e.g., ESVs). These comparisons are done at each of the EUs and their applicable media to identify COPECs. In addition, the results and discussion section contains the preliminary CSM, site-specific receptors, and other information pertaining to Level III.

7.4.1 Data and Media Evaluation Results

Tables showing the results of the data and media evaluation screening to initially identify COPECs for surface soil, sediment, and surface water are presented in Appendix Tables M-5 through M-7, respectively. A summary of these results of the data and media evaluation screening is provided below.

Surface Soil. Fifty-six detected COIs, including 23 inorganics, 10 explosives, 20 SVOCs, and 3 VOCs were inputted to the data and media evaluation for surface soil (Appendix Table M-5). One inorganic (manganese) was eliminated from being a COPEC due to a frequency of detection less than 5% and not being a PBT compound. Thus, 55 of the 56 COIs were deemed to be COPECs because they met one or more of the following criteria: they were PBTs and/or their frequency of detection exceeded 5%, and/or their MDC exceeded the background value (or there was not a reported background value). The COPECs were carried forward to the media screening step, which is discussed in Section 7.4.2.

Sediment. Forty detected COIs, including 22 inorganics, 4 explosives, 12 SVOCs, and 2 VOCs were inputted to the data and media evaluation for RQL sediment (Appendix Table M-6). Seven inorganics were eliminated from being COPECs because their MDCs did not exceed the Ohio EPA SRVs and they were not PBTs. One inorganic COI did not have a SRV but was eliminated because its concentration was below background. Thus, 32 of the inputted COIs were deemed to be COPECs because they met one or more of the following criteria: they were PBTs and/or their frequency of detection exceeded 5%, and/or their MDC exceeded the SRV or background value (or there was not a reported SRV or background value). The COPECs were carried forward to the media screening, which is discussed in Section 7.4.2.

Surface Water. Twenty-eight detected COIs, including 23 inorganics, 1 explosive, 1 pesticide, and 3 VOCs were inputted to the data and media evaluation for RQL surface water (Appendix Table M-7). One of the inorganics was eliminated from being a COPEC because its MDC did not exceed the background value and it was not a PBT. Thus, 27 of the inputted COIs were deemed to be COPECs because they met one or more of the following criteria: they were PBTs and/or their frequency of detection exceeded 5%, and/or their MDC exceeded the background value (or there was not a reported background value). The COPECs were carried forward to the media screening, which is discussed in Section 7.4.2.

7.4.2 Media Screening Results

Tables providing the screening values and chemical criteria for these comparisons are found in Appendix Tables M-2 through M-4. Tables showing the results of the media screening for surface soil, sediment, and surface water are presented in Appendix Tables M-8 through M-10, respectively. Summary results of the retained COPECs following the media screening are presented in Tables 7-2 through 7-4 and are discussed below.

7.4.2.1 Surface soil media screening

The media screening for surface soil is shown in Appendix Table M-8. A summary of surface soil COPECs that were retained following the media screening is presented in Table 7-2.

Fifty-five COPECs were inputted into the media screening from the data and media evaluation, including 22 inorganics, 10 explosives, 20 SVOCs, and 3 VOCs (Appendix Table M-8). Seven of the inputted COPECs were not retained because their maximum detects were below their ESVs and they were not PBT compounds. The ten eliminated COPECs included five inorganics (barium, beryllium, cobalt, silver, and thalliium), two explosives (2,4-DNT and 2,4,6-), and three VOCs (acetone, 2-butanone, and methylene chloride). Thus, 45 COPECs were retained, which included 17 inorganics, 8 explosives, and 20 SVOCs.

Of the 45 retained COPECs, 31 had maximum detects that exceeded their ESV (14 inorganics, 2 explosives, and 15 SVOCs), 12 had no ESVs (4 inorganics, 6 explosives, and 2 SVOCs), and 5 were COPECs solely due to being PBT compounds (all were SVOCs) (Table 7-2). Eighteen of the retained COPECs (cadmium, lead, mercury, zinc, and 14 SVOCs) had maximum detects that exceeded the ESV and were also PBT compounds.

7.4.2.2 Sediment media screening

The media screening for RQL sediment is shown in Appendix Table M-9. A summary of sediment COPECs that were retained following the media screening is presented in Table 7-3.

Thirty-three sediment COPECs were inputted into the media screening from the data and media evaluation, including 14 inorganics, 4 explosives, 12 SVOCs, and two VOCs (Appendix Table M-9). Three of the inputted COPECs were not retained because their maximum detects were below their ESVs and they were not PBT compounds. The three eliminated COPECs included two inorganics (chromium and cobalt) and one VOC (2-butanone). Thus, 29 COPECs were retained, which included 12 inorganics, 4 explosives, 12 SVOCs, and 1 VOC.

Of the 29 retained COPECs, 16 had maximum detects that exceeded their ESV (7 inorganics, 1 explosive, 7 SVOCs, and 1 VOC), 8 had no ESVs (4 inorganics, 3 explosives, and 1 SVOC), and 5 were COPECs solely due to being PBT compounds (mercury and 4 SVOCs) (Table 7-3). Ten of the retained COPECs (cadmium, lead, zinc, and 7 SVOCs) had maximum detects that exceeded the ESV and were also PBT compounds.

Table 7-2. Summary of Surface Soil COPECs for the Ramsdell Quarry Landfill and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > ESV	PBT Compound	No ESV
Inorganics			
Aluminum	X		
Antimony	X		
Arsenic	X		
Cadmium	X	X	
Calcium			X
Chromium	X		
Copper	X		
Iron	X		
Lead	X	X	
Magnesium			X
Mercury	X	X	
Nickel	X		
Potassium			X
Selenium	X		
Sodium			X
Vanadium	X		
Zinc	X	X	
Organics-Explosives			
2-Amino-4,6-dinitrotoluene			X
4-Amino-2,6-dinitrotoluene			X
1,3-Dinitrobenzene	X		
2,6-Dinitrotoluene	X		
HMX			X
Nitroglycerin			X
2-Nitrotoluene			X
RDX			X
Organics-Semivolatiles			
2-Methylnaphthalene	X		
Acenaphthene	X	X	
Acenaphthylene		X	
Anthracene		X	
Benzo(*a*)anthracene	X	X	
Benzo(*a*)pyrene	X	X	
Benzo(*b*)fluoranthene	X	X	
Benzo(*g,h,i*)perylene	X	X	
Benzo(*k*)fluoranthene	X	X	
Bis(2-ethylhexyl)phthalate		X	

Table 7-2. Summary of Surface Soil COPECs for the Ramsdell Quarry Landfill and Their Rationale for Retention (continued)

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > ESV	PBT Compound	No ESV
Carbazole		X	X
Chrysene	X	X	
Dibenzo(*a,h*)anthracene	X	X	
Dibenzofuran		X	X
Fluoranthene	X	X	
Fluorene	X	X	
Indeno(1,2,3-*cd*)pyrene	X	X	
Naphthalene	X	X	
Phenanthrene	X	X	
Pyrene	X	X	

COPEC = Constituent of potential ecological concern.
ESV = Ecological screening value.
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
PBT = Persistent, bioaccumulative, and toxic.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
"X" = COPEC was retained based on this rationale.

Table 7-3. Summary of Sediment COPECs for the Ramsdell Quarry Landfill and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > ESV	**PBT Compound**	**No ESV**
Inorganics			
Arsenic	X		
Cadmium	X	X	
Calcium			X
Copper	X		
Cyanide	X		
Iron			X
Lead	X	X	
Magnesium			X
Manganese			X
Mercury		X	
Nickel	X		
Zinc	X	X	
Organics-Explosives			
2,4-Dinitrotoluene	X		
HMX			X
Nitrocellulose			X
3-Nitrotoluene			X
Organics-Semivolatiles			
Anthracene	X	X	
Benzo(*a*)anthracene	X	X	
Benzo(*a*)pyrene	X	X	
Benzo(*b*)fluoranthene		X	
Benzo(*g,h,i*)perylene		X	
Benzo(*k*)fluoranthene		X	
Carbazole		X	X
Chrysene	X	X	
Fluoranthene	X	X	
Indeno(1,2,3-*cd*)pyrene		X	
Phenanthrene	X	X	
Pyrene	X	X	
Organics-Volatiles			
Acetone	X		

COPEC = Constituent of potential ecological concern.
ESV = Ecological screening value.
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
PBT = Persistent, bioaccumulative, and toxic compound.
"X" = COPEC was retained based on this rationale.

Table 7-4. Summary of Surface Water COPECs for the Ramsdell Quarry Landfill and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > OAC WQC	**PBT Compound**	**No OAC WQC**
Inorganics			
Aluminum			X
Cadmium		X	
Calcium			X
Chloride			X
Cobalt	X		
Copper	X		
Iron			X
Lead	X	X	
Magnesium			X
Manganese			X
Mercury		X	
Nitrate/Nitrite			X
Potassium			X
Sulfate			X
Zinc	X	X	
Organics-Pesticides			
Aldrin		X	X
Organics-Volatiles			
Acetone			X

COPEC = Constituent of potential ecological concern.
OAC WQC= Ohio Administrative Code Water Quality Criteria.
PBT = Persistent, bioaccumulative, and toxic compound.
"X" = COPEC was retained based on this rationale.

7.4.2.3 Surface water media screening

The media screening for RQL surface water is shown in Appendix Table M-10. A summary of surface water COPECs that were retained following the media screening is presented in Table 7-4.

Twenty-seven surface water COPECs were inputted into the media screening from the data and media evaluation, including 22 inorganics, 1 explosive, 1 pesticide, and 3 VOCs (Appendix Table M-10). Ten of the inputted COPECs (7 inorganics, 1 explosive, and 2 VOCs) were not retained because their maximum detects were below their OAC WQC. Thus, 17 COPECs were retained, which included 15 inorganics, 1 pesticide, and 1 VOC.

Of the 17 retained COPECs, 4 had maximum detects that exceeded the OAC WQC, 11 had no OAC WQC (9 inorganics, 1 pesticide, and 1 VOC), and 2 were COPECs solely due to being PBT compounds (cadmium and mercury) (Table 7-4). Three of the retained COPECs (lead, zinc, and aldrin) had maximum detects that exceeded the ESV and were also PBT compounds.

7.4.2.4 Conclusion and extension of the SERA

Ohio EPA guidance (Ohio EPA 2003) states, "For a site to present a potential for hazard, it must exhibit the following three conditions: (a) contain COPECs in media at detectable and biologically significant concentrations, (b) provide exposure pathways linking COPECs to ecological receptors, and (c) have endpoint species that either utilize the site, are not observed to utilize the site but habitat is such that the endpoints species should be present, are present nearby, or can potentially come into contact with site-related COPECs." This Level II screen has shown that these three conditions are met at the RQL site.

The Level II report "identifies site-specific receptors, relevant and complete exposure pathways and other pertinent information for conducting a Level III ERA if a SMDP was chosen to continue the ecological assessment in a Level III ERA" (Ohio EPA 2003). The Scientific Management Decision Point (SMDP) was made before the Level II evaluation that if the conditions for potential for hazard were demonstrated at the RQL site, the preliminary information for a Level III ERA would be included in the SERA report. The following sections present ecological CSMs (Section 7.4.3), selection of site-specific ecological receptor species (Section 7.4.4), relevant and complete exposure pathways (Section 7.4.5), and candidate ecological assessment endpoints and measures (Section 7.4.6).

7.4.3 Ecological Conceptual Site Models

Ecological CSMs depict and describe the known and expected relationships among the stressors, pathways, and assessment endpoints that are considered in the risk assessment, along with a rationale for their inclusion. Two ecological CSMs are presented for this Level II Screen. One ecological CSM is associated with the media screening of the Level II Screen (Figure 7-1). The other ecological CSM (Figure 7-2) represents the Level III Baseline. The ecological CSMs for the RQL site were developed using the available site-specific information and professional judgment. The contamination mechanism, source media, transport mechanisms, exposure media, exposure routes, and ecological receptors for the ecological CSMs are described below.

7.4.3.1 Contamination source

The contamination source includes releases from historic site operations. Chapter 2.0 describes the types of historical operations that took place at the site.

7.4.3.2 Source media

The source medium is soil. For the screening level ERA, surface soil is defined as 0 to 2 ft bgs. Contaminants released from historic site operations went directly into the surrounding soil, making soil the source medium.

7.4.3.3 Transport mechanisms

Transport mechanisms at the site include volatilization into the air, biota uptake, erosion to surface water and sediment, and leaching to groundwater. Biota uptake is a transport mechanism because some of the site contaminants are known to accumulate in biota, and those biota are free to move around. The deposition of eroded soils containing site contaminants into surface water and sediment is also a valid transport mechanism for both ecological CSMs.

7.4.3.4 Exposure media

Sufficient time (over 10 years) has elapsed for contaminants in the source media to have migrated to potential exposure media, resulting in possible exposure of plants and animals that come in contact with these media. Potential exposure media include air, surface soil, food chain, surface water, and sediment. Subsurface soil is not being evaluated at RQL. Groundwater is not considered an exposure medium because ecological receptors are unlikely to contact groundwater at a depth of greater than 5 ft bgs. Groundwater could outcrop into surface water as a seep or spring, but is not considered an exposure

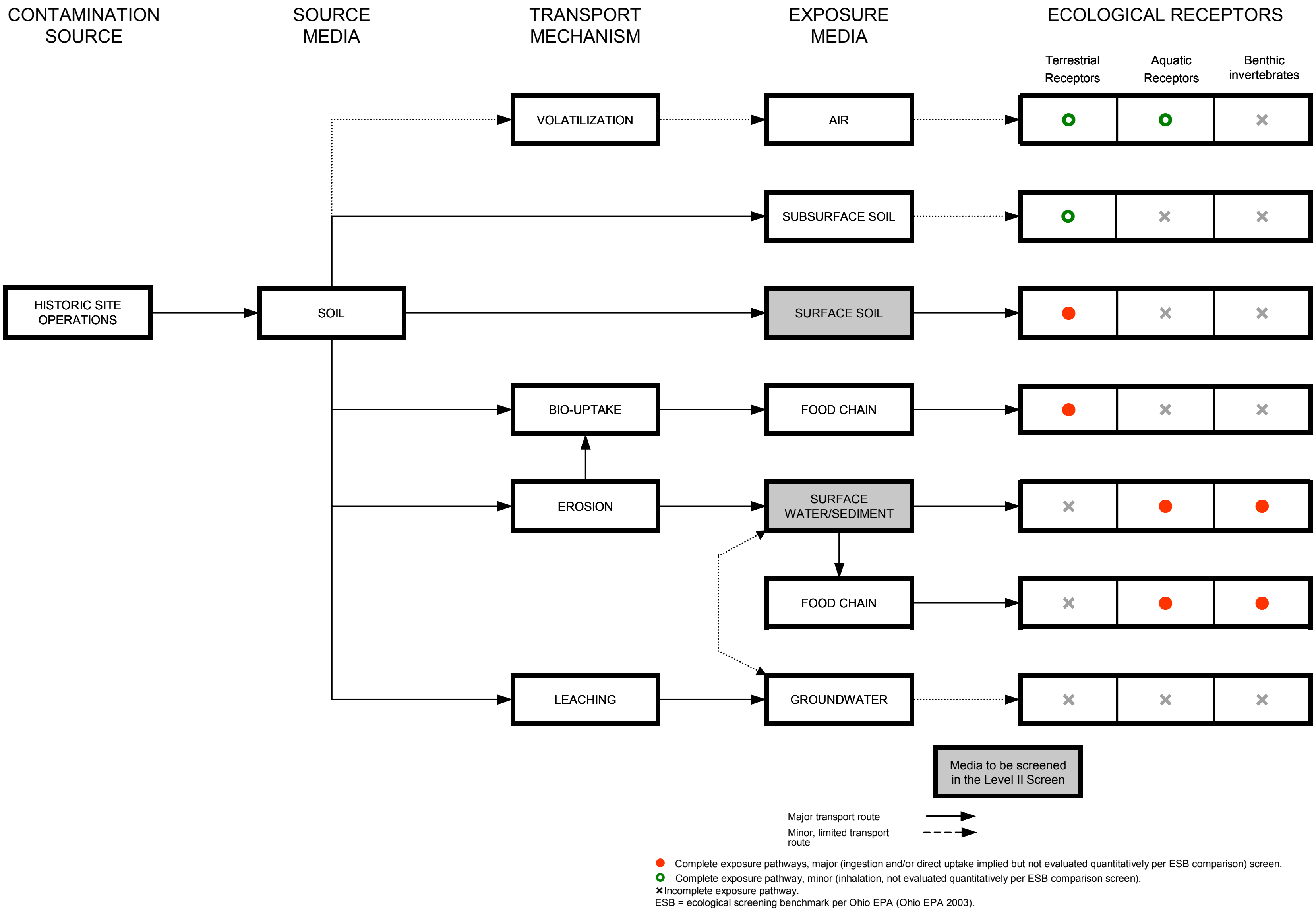
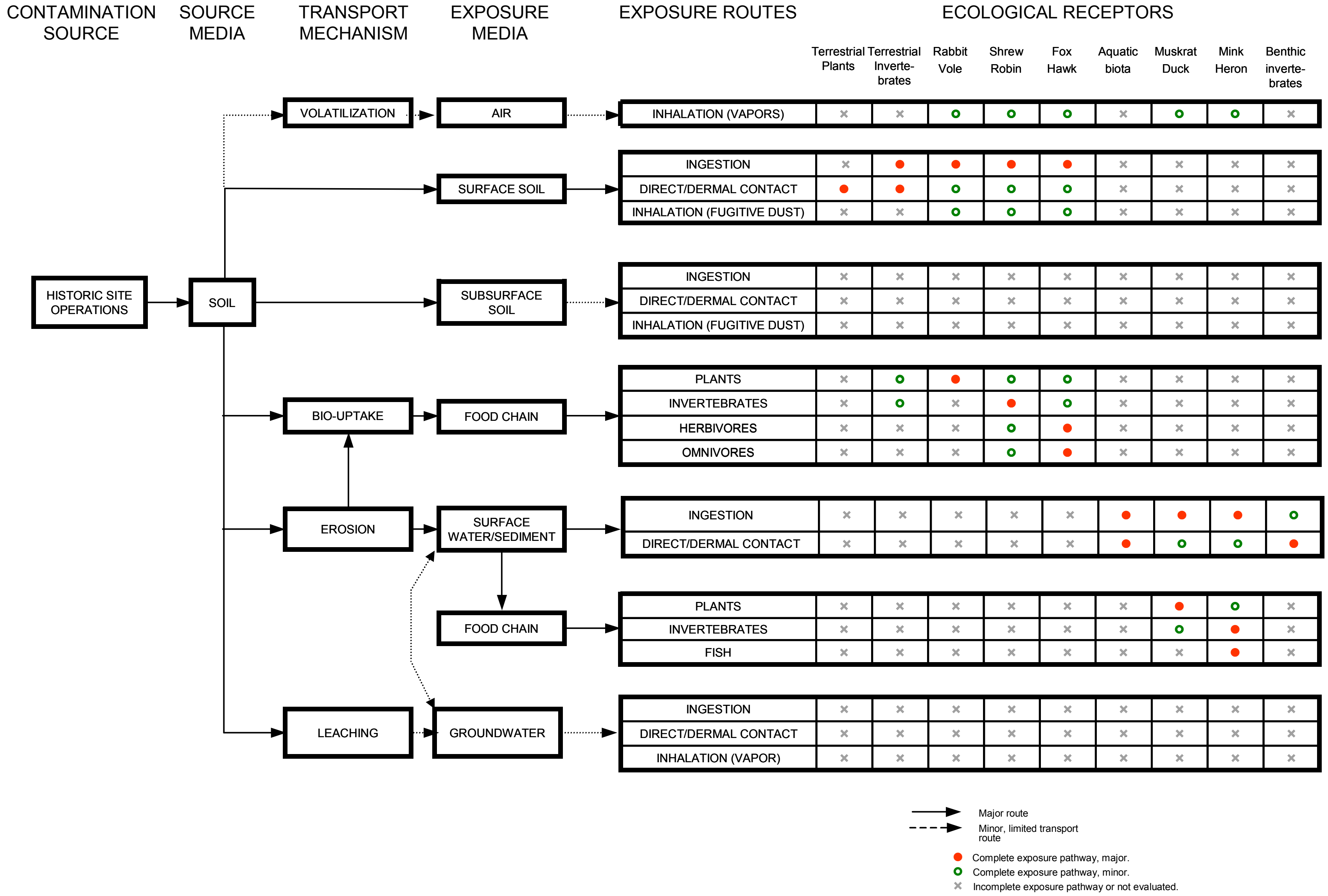


Figure 7-1. Conceptual Site Model for Level II Screen – Pathways for Ecological Exposure at the Ramsdell Quarry Landfill Site



Exposure Media	Exposure Routes	Terrestrial Plants	Terrestrial Inverte-brates	Rabbit Vole	Shrew Robin	Fox Hawk	Aquatic biota	Muskrat Duck	Mink Heron	Benthic inverte-brates
AIR	INHALATION (VAPORS)	×	×	○	○	○	×	○	○	×
SURFACE SOIL	INGESTION	×	●	●	●	●	×	×	×	×
	DIRECT/DERMAL CONTACT	●	●	○	○	○	×	×	×	×
	INHALATION (FUGITIVE DUST)	×	×	○	○	○	×	×	×	×
SUBSURFACE SOIL	INGESTION	×	×	×	×	×	×	×	×	×
	DIRECT/DERMAL CONTACT	×	×	×	×	×	×	×	×	×
	INHALATION (FUGITIVE DUST)	×	×	×	×	×	×	×	×	×
FOOD CHAIN	PLANTS	×	○	●	○	○	×	×	×	×
	INVERTEBRATES	×	○	×	●	○	×	×	×	×
	HERBIVORES	×	×	×	○	●	×	×	×	×
	OMNIVORES	×	×	×	○	●	×	×	×	×
SURFACE WATER/SEDIMENT	INGESTION	×	×	×	×	×	●	●	●	○
	DIRECT/DERMAL CONTACT	×	×	×	×	×	●	○	○	●
FOOD CHAIN	PLANTS	×	×	×	×	×	×	●	○	×
	INVERTEBRATES	×	×	×	×	×	×	○	●	×
	FISH	×	×	×	×	×	×	×	●	×
GROUNDWATER	INGESTION	×	×	×	×	×	×	×	×	×
	DIRECT/DERMAL CONTACT	×	×	×	×	×	×	×	×	×
	INHALATION (VAPOR)	×	×	×	×	×	×	×	×	×

Figure 7-2. Conceptual Site Model for Level III Screen – Pathways for Ecological Exposure at the Ramsdell Quarry Landfill Site

medium until it does so. Soil, surface water, sediment, and food chain are the four principal exposure media for the RQL site.

7.4.3.5 Exposure routes

Exposure routes are functions of the characteristics of the media in which the sources occur, and how both the released chemicals and receptors interact with those media. For example, chemicals in surface water may be dissolved or suspended as particulates and be very mobile, whereas those same constituents in soil may be much more stationary. The ecology of the receptors is important because it dictates their home range, whether the organism is mobile or immobile, local or migratory, burrowing or above ground, plant eating, animal eating, or omnivorous.

For the Level II Screen, specific exposure routes were not identified because the screen is not receptor specific and only focuses on comparison of MDCs of chemicals in the exposure media against published ecological toxicological benchmark concentrations derived for those media. However, the Level III Baseline ecological CSM (Figure 7-2) will identify specific exposure routes and indicates whether the exposure routes from the exposure media to the ecological receptors are major or minor. Major exposure routes are evaluated quantitatively, whereas minor routes are evaluated qualitatively. The Level III Baseline ecological CSM (Figure 7-2) shows a major exposure route of soil to terrestrial plants and animals and an incomplete exposure route of upper groundwater to terrestrial and aquatic plants and animals. Groundwater is assumed not to be directly contacted by ecological receptors.

The major exposure routes for chemical toxicity from surface soil include ingestion (for terrestrial invertebrates, rabbits, voles, shrews, robins, foxes, and hawks) and direct contact (for terrestrial plants and invertebrates). The ingestion exposure route for rabbits, voles, shrews, robins, foxes, and hawks includes soil, as well as plant and/or animal food (i.e., food chain), that was exposed to the surface soil. Minor exposure routes for surface soil include direct contact and inhalation of fugitive dust (for rabbits, voles, shrews, robins, foxes, and hawks). The major exposure routes for surface water include ingestion (for aquatic biota, muskrats, ducks, mink, and herons) and direct contact (for aquatic biota and benthic invertebrates). Minor exposure pathways for surface water and sediment include direct contact and inhalation (for muskrats, ducks, mink, and herons). The major exposure routes for sediment include ingestion (for aquatic biota, muskrats, ducks, mink, and herons) and direct contact (for aquatic biota and benthic invertebrates). The ingestion exposure routes for aquatic biota (including vertebrate mammals and birds) include sediment and surface water (as applicable), as well as plant and/or animal food (food chain), that were exposed to the sediment or surface water.

Exposure to groundwater is an incomplete pathway for all terrestrial and aquatic ecological receptors because groundwater is too deep beneath ground level for there to be direct exposure to any of the receptors. If the groundwater outcrops via seeps or springs into wetlands or ditches, it becomes part of the surface water and would be evaluated in the surface water pathway.

7.4.3.6 Ecological receptors

For the Level II screen, specific ecological receptors were not identified, but terrestrial and aquatic biota were each considered as a whole. However, for the Level III Baseline, terrestrial and aquatic ecological receptors, as well as riparian receptors, would be identified in the ecological CSM (Figure 7-2). The terrestrial receptors include plants, terrestrial invertebrates (earthworms), rabbits, voles, shrews, robins, foxes, and hawks. The aquatic receptors include benthic invertebrates and aquatic biota. Aquatic herbivore receptors are represented by the muskrat and the mallard duck. The riparian carnivores include mink and herons. These receptors are discussed in more detail in Section 7.4.4.

7.4.4 Selection of Site-specific Ecological Receptor Species

The selection of ecological receptors for the site-specific analysis screen was based on plant and animal species that do or could occur in the terrestrial and aquatic habitats at the site. Three criteria were used to identify the site-specific receptors.

1. **Ecological Relevance.** The receptor has or represents a role in an important function such as energy fixation (e.g., plants), nutrient cycling (e.g., earthworms), and population regulation (e.g., hawks). Receptor species were chosen to include representatives of all applicable trophic levels identified by the ecological CSM for the site. These species were selected to be predictive of assessment endpoints (including protected species/species of special concern and recreational species).
2. **Susceptibility.** The receptor is known to be sensitive to the chemicals detected at the site, and given their food and habitat preferences, their exposure is expected to be high. The species have a likely potential for exposure based upon their residency status, home range size, sedentary nature of the organism, habitat compatibility, exposure to contaminated media, exposure route, and/or exposure mechanism compatibility. Ecological receptor species were also selected based on the availability of toxicological effects and exposure information.
3. **Management Goals.** Valuable roles in erosion control (e.g., plants), societal values [e.g., trapping for fur (mink) and small game hunting (rabbits)], and regulatory protection [e.g., Migratory Bird Act (robins, hawks, mallards, and herons) and Migratory Bird Hunting Stamp Act (mallards)]. The ecosystem functions of the ecological receptor species (foodweb interactions, keystone species, vital to ecosystem function, dominant species or tolerant/intolerant species) were considered during the selection process.

At RQL, the following types of ecological receptors are likely to be present: terrestrial plants, terrestrial invertebrates, cottontail rabbits (*Sylvilagus floridanus*), meadow voles (*Microtus pennsylvanicus*), short-tailed shrews (*Blarina brevicauda*), American robins (*Turdus migratoris*), red foxes (*Vulpes vulpes*), red-tailed hawks (*Buteo jamaicensis*), sediment-dwelling biota, aquatic biota, muskrats (*Ondatra zibenthicus*), mallard ducks (*Anas platyrhynchos*), mink (*Mustella vison*), and great blue herons (*Ardea herodias*). Each of these receptors is described in Sections 7.4.4.1 (for terrestrial exposures) or 7.4.4.2 (for aquatic and riparian exposures).

7.4.4.1 Terrestrial exposure classes and receptors

Terrestrial exposures, receptors, and justification for their selection for the site-specific analysis screen are presented below.

Terrestrial Vegetation Exposure to Soil

Terrestrial vegetation exposure to soil is applicable to the RQL site. Terrestrial plants have ecological relevance because they represent the base of the food web and are the primary producers that turn energy from the sun into organic material (plants) that provides food for many animals. There is sufficient habitat present for them at the site. In addition, plants are important in providing shelter and nesting materials to many animals, thus, plants are a major component of habitat. Plants provide natural cover and stability to soil and stream banks, thereby reducing soil erosion.

Terrestrial plants are susceptible to toxicity from chemicals. Plants have roots that are in direct contact with surface soil, which provides them with direct exposure to contaminants in the soil. They also can have exposure to contaminants via direct contact on the leaves. There are published toxicity benchmarks for plants (Efroymson et al. 1997c), and there are management goals for plants because of their importance in erosion control. Thus, there is sufficient justification to warrant plants as a receptor for the RQL site.

Terrestrial Invertebrate Exposure to Soil

Terrestrial invertebrate exposure to soil is applicable to soils for the RQL site. Earthworms represent the receptor for the terrestrial invertebrate class, and there is sufficient habitat present for them on-site. Earthworms have ecological relevance because they are important for decomposition of detritus and for energy and nutrient cycling in soil (Efroymson et al 1997b). Earthworms are probably the most important of the terrestrial invertebrates for promoting soil fertility because they process much soil.

Earthworms are susceptible to exposure to, and toxicity from, COPECs in soil. Earthworms are nearly always in contact with soil and ingest soil, which results in constant exposure. Earthworms are sensitive to various chemicals. Toxicity benchmarks are available for earthworms (Efroymson et al. 1997b). Although management goals for earthworms are not immediately obvious, the important role of earthworms in soil fertility cannot be overlooked. Thus, there is sufficient justification to warrant earthworms as a receptor for the RQL site.

Mammalian Herbivore Exposure to Soil

Mammalian herbivore exposure to soil is applicable to the RQL site. Cottontail rabbits and meadow voles represent mammalian herbivore receptors, and there is suitable habitat present for them at the site. Both species have ecological relevance by consuming vegetation, which helps in the regulation of plant populations and in the dispersion of some plant seeds. Small herbivorous mammals such as cottontail rabbits and voles are components of the diet of terrestrial top predators.

Both cottontail rabbits and meadow voles are susceptible to exposure to, and toxicity from, COPCs in soil and vegetation. Herbivorous mammals are exposed primarily through ingestion of plant material and incidental ingestion of contaminated surface soil containing chemicals. Exposures by inhalation of COPCs in air or on suspended particulates, as well as exposures by direct contact with soil, were assumed to be negligible. Dietary toxicity benchmarks are available for many COPCs for mammals (Sample et al. 1996), and there are management goals for rabbits because they are an upland small game species protected under Ohio hunting regulations. There are no specific management goals for meadow voles at RQL. However, because of the management goals for rabbits, plus the ecological relevance and susceptibility to contamination for both species, there is sufficient justification to warrant cottontail rabbits and meadow voles as receptors for the RQL site.

Insectivorous Mammal and Bird Exposure to Soil

Insectivorous mammal and bird exposure to soil is applicable to the RQL site. Short-tailed shrews and American robins represent the receptors for the insectivorous mammal and bird terrestrial exposure class, respectively. There is sufficient, suitable habitat present at the site for these receptors. Both species have ecological relevance because they help to control aboveground invertebrate community size by consuming large numbers of invertebrates. Shrews and robins are a prey item for terrestrial top predators.

Both short-tailed shrews and American robins are susceptible to exposure to, and toxicity from, COPCs in soil, as well as contaminants in vegetation and terrestrial invertebrate. Insectivorous mammals such as short-tailed shrews and birds such as American robins are primarily exposed by ingestion of contaminated prey (e.g., earthworms, insect larvae, and slugs), as well as ingestion of soil. In addition, shrews ingest a small amount of leafy vegetation, and the robin's diet consists of 50% each of seeds and fruit. Dietary toxicity benchmarks are available for mammals and birds (Sample et al. 1996). Both species are recommended as receptors because there can be different toxicological sensitivity between mammals and birds exposed to the same contaminants. There are management goals for robins because they are federally protected under the Migratory Bird Treaty Act of 1993, as amended. There are no specific management goals for shrews at the site. Based on the management goals for robins, plus the susceptibility to contamination and ecological relevance for both species, there is sufficient justification to warrant shrews and robins as receptors for the RQL site.

Terrestrial Top Predators

Exposure of terrestrial top predators is applicable to the RQL site. Red foxes and red-tailed hawks represent the mammal and bird receptors for the terrestrial top predator exposure class, respectively, and there is a limited amount of suitable habitat present for them at the site. Both species have ecological relevance because as representatives of the top of the food chain for the site terrestrial EUs, they control populations of prey animals such as small mammals and birds.

Both red foxes and red-tailed hawks are susceptible to exposure to, and toxicity from, COPECs in soil, vegetation, and/or animal prey. Terrestrial top predators feed on small mammals and birds that may accumulate constituents in their tissues following exposure at the site. There is a potential difference in toxicological sensitivity between mammals and birds exposed to the same COPCs so it is prudent to examine a species from each taxon (Mammalia and Aves, respectively). Red foxes are primarily carnivorous but consume some plant material. The red-tailed hawk consumes only animal prey. The foxes may incidentally consume soil.

There are management goals for both species. Laws (Ohio trapping season regulations for foxes, and federal protection of raptors under the Migratory Bird Treaty Act) also protect these species. In addition, both species are susceptible to contamination and have ecological relevance as top predators in the terrestrial ecosystem. Thus, there is sufficient justification to warrant these two species as receptors for the RQL site.

7.4.4.2 Aquatic and riparian exposure receptors

The aquatic exposures, receptors, and justification for why they are relevant for the RQL site are presented below.

Exposure of Aquatic Biota to Water

Exposure of aquatic biota to water is applicable to the RQL site. Aquatic biota (e.g., aquatic plants, invertebrates, and fish) represent the ecological receptors for the aquatic biota exposure class, and there is habitat for them at this site. Aquatic biota have ecological relevance because they represent the range of living organisms in the aquatic ecosystem and they provide food for various predators.

Aquatic biota are susceptible to exposure to, and toxicity from, COPECs in surface water. The exposure concentration for aquatic biota is assumed to be equal to the measured environmental concentration because the biota have constant contact with water and the aquatic toxicity benchmarks that are used are expected to protect aquatic life from all exposure pathways, including ingestion of surface water, contaminated plants, and animals. Toxicity benchmarks are available for aquatic biota (Suter and Tsao 1996), but Ohio state WQC for surface water must also be met.

There are management goals for aquatic biota in laws that specify Ohio water quality standards to support designated uses (e.g., survival and propagation of aquatic life) for waters of the state. In addition, aquatic biota are susceptible to contamination by virtue of continual exposure in water, and they have ecological relevance for biota within the aquatic and terrestrial ecosystems. Thus, there is sufficient justification to warrant aquatic biota as a receptor for the RQL site.

Exposure of Sediment-Dwelling Biota to Sediment

Sediment-dwelling biota exposure to sediment is applicable to the site-specific analysis. Benthic invertebrates such as aquatic insect larvae like caddisflies (Trichoptera), mayflies (Ephemeroptera), and midges (Chironomidae), as well as non-insects such as crayfish (Decapoda), snails (Gastropoda), and clams and bivalves (Pelycypoda), represent the receptors for the sediment-dwelling biota aquatic exposure class. These biota have ecological relevance because they provide food for many aquatic species and also for some terrestrial mammals and birds such as raccoons, mallards, and herons.

Benthic invertebrates are susceptible to exposure to, and toxicity from, COPECs in sediment. These biota have direct contact with sediment and sediment pore water. Toxicity benchmarks are available for benthic invertebrates (Jones, Suter, and Hull 1997).

There are management goals for sediment-dwelling biota because the condition of these biological communities is linked to assessment of Ohio water quality use attainment in streams. These biota are susceptible to contamination by virtue of continual exposure in sediment, and they have ecological relevance as a major food source for aquatic biota. Thus, there is sufficient justification to warrant sediment-dwelling biota as a receptor for the Level III Baseline.

Herbivore Exposure to Water, Sediment, and the Aquatic/Sediment Food Web

Aquatic herbivores like muskrats and mallard ducks are exposed to water and sediment so these exposures are applicable to the RQL site. There is also suitable habitat for them at the site. Muskrats eat aquatic vegetation. Mallard ducks are surface-feeding ducks that obtain much of their food by dabbling in shallow water and filtering through soft mud with their beaks. Their food consists mostly of seeds of aquatic plants, as well as aquatic invertebrates (EPA 1993). Animal matter accounts for approximately 67 to 90% of the diet for breeding female ducks during the spring and summer, but decrease to less than 10% of the diet during the winter. Mallards have ecological relevance as important components of the aquatic food web. As aquatic herbivores, muskrats and mallards help maintain the size and composition of the aquatic vegetation community.

Muskrats and mallards are susceptible to exposure to, and toxicity from, COPECs in surface water and aquatic vegetation. The potential for exposure to contaminants is high because they consume aquatic and sediment-dwelling plants that can accumulate high concentrations of some chemicals from water. In addition, these species can have further exposure via ingestion of contaminants in surface water that they use for a drinking water source and incidentally ingested sediment. Since there is a potential difference in the toxicological sensitivity of mammals and birds exposed to the same COPECs, one mammal and one bird were examined for exposure to water, sediment, and the aquatic food chain. Dietary toxicity benchmarks for many inorganic and some organic substances are available for mammals and birds (Sample et al. 1996).

There are management goals for muskrats and mallards. For example, there are Ohio trapping season regulations for muskrats, and mallards are federally protected under the Migratory Bird Treaty Act of 1993, as amended. Mallard ducks are also federally protected as a game species under the Migratory Bird Hunting and Conservation Stamp Act of 1934, as amended. Both species are susceptible to COPECs, especially via ingestion exposure, and they have ecological relevance. Thus, there is sufficient justification to warrant these receptors for the RQL site.

Riparian Carnivores

Exposure of predators to aquatic biota is applicable to the RQL site because PBT chemicals are present at the site. There is also suitable habitat for these receptors at the site. Exposure evaluation for piscivores (fish-eating predators) is required by Ohio EPA (2003) when a PBT compound or a COPEC with no screening benchmark is found in surface water or sediment. Mink and great blue herons are riparian carnivores chosen to represent mammalian and bird receptors for the fish-eating predator exposure class, respectively. Riparian carnivores feed predominantly in and along the banks of streams. Both species have ecological relevance because as piscivorous riparian carnivores, they are important components of the aquatic food web representing the top predators. As top predators, they help limit the population size for some aquatic and some sediment-dwelling biota communities.

Both species are susceptible to exposure to, and toxicity from, COPECs in surface water, aquatic biota, and sediment-dwelling biota. The potential for exposure to COPECs is high for these two species because they consume fish, which can accumulate high concentrations of some chemicals from water. In addition, both species can have further exposure via ingestion of COPECs in surface water that is used for a drinking water source. Dietary toxicity benchmarks are available for mammals and birds (Sample et al. 1996). There can be differences in toxicological sensitivity between mammals and birds exposed to the same COPEC, so both species are appropriate.

There are management goals for both species because regulations protect both species. For example, mink are regulated by Ohio trapping regulations because they are fur-bearing mammals. Great blue herons are federally protected under the Migratory Bird Treaty Act of 1993, as amended. Both species are susceptible to contamination, especially via ingestion exposure routes, and they have ecological relevance as predators. Thus, there is sufficient justification to warrant these two receptors for the RQL site.

7.4.5 Relevant and Complete Exposure Pathways

Relevant and complete exposure pathways for the ecological receptors at RQL were described in Section 7.4.3 on the ecological CSMs. As previously discussed, there are relevant and complete exposure pathways for various ecological receptors including terrestrial vegetation and invertebrates; aquatic and sediment-dwelling biota; and terrestrial and aquatic herbivores, insectivores, and carnivores. Thus, these types of receptors could be exposed to COPECs in abiotic media at the RQL site.

7.4.6 Candidate Ecological Assessment Endpoints and Measures

The protection of ecological resources, such as habitats and species of plants and animals, is a principal motivation for conducting screening level ERAs. Key aspects of ecological protection are presented as management goals, which are general goals established by legislation or agency policy and based on societal concern for the protection of certain environmental resources. For example, environmental protection is mandated by a variety of legislation and governmental agency policies (e.g., CERCLA and NEPA). Other legislation includes the ESA (16 *U.S. Code* 1531-1544, 1993, as amended) and the Migratory Bird Treaty Act (16 *U.S. Code* 703-711, 1993, as amended). To evaluate whether a management goal has been met, assessment endpoints, measures of effects, and decision rules were formulated. The management goals, assessment endpoints, measures of effects, and decision rules are discussed below.

There are two management goals for RQL. However, the assessment endpoints differ between the general screen and the site-specific analysis screen. The management goals for the screening level ERA are:

- Management Goal 1: Protect terrestrial plant and animal populations from adverse effects due to the release or potential release of chemical substances associated with past site activities.

- Management Goal 2: Protect aquatic plant and animal populations and communities from adverse effects due to the release or potential release of chemical substances associated with past site activities.

Ecological assessment endpoints are selected to determine whether these management goals are met at the unit. An ecological assessment endpoint is a characteristic of an ecological component that may be affected by exposure to a stressor (e.g., COPEC). Assessment endpoints are "explicit expressions of the actual environmental value that is to be protected" (EPA 1992a). Assessment endpoints often reflect environmental values that are protected by law, provide critical resources, or provide an ecological function that would be significantly impaired if the resource was altered. Unlike the HHRA process, which focuses on individual receptors, the screening level ERA focuses on populations or groups of interbreeding non-human, non-domesticated receptors. Accordingly, assessment endpoints generally refer to characteristics of populations and communities. In the screening level ERA process, risks to individuals are assessed only if they are protected under the ESA or other species-specific legislation, or if the species is a candidate for listing as a T&E species.

Given the diversity of the biological world and the multiple values placed on it by society, there is no universally applicable list of assessment endpoints. Therefore, Ohio EPA's *Ecological Risk Assessment Guidance Document* (Ohio EPA 2003) was used to select assessment endpoints.

For the Level II Screen, the assessment endpoints are any potential adverse effects on ecological receptors, where receptors are defined as any plant or animal population, communities, habitats, and sensitive environments (Ohio EPA 2003). Although the assessment endpoints for the Level II Screen are associated with Management Goals 1 and 2, specific receptors are not identified with the assessment endpoints.

For the Level III Baseline, the assessment endpoints would be more specific and stated in terms of types of specific ecological receptors associated with each of the two management goals. Assessment endpoints 1, 2, 3, and 4 entail the growth, survival, and reproduction of terrestrial receptors such as vegetation and terrestrial invertebrates, herbivorous mammals, worm-eating/insectivorous mammals and birds, and carnivorous top predator mammals and birds, respectively. Assessment endpoints 1 through 4 are associated with Management Goal 1, protection of terrestrial populations and communities. Assessment endpoint 5 deals with the growth, survival, and reproduction of sediment-dwelling biota, which is associated with Management Goal 2, protection of aquatic populations and communities. Assessment endpoints 6, 7, and 8 are also associated with Management Goal 2, and deal with the growth, survival, and reproduction of aquatic biota, aquatic herbivores, and riparian carnivores, respectively.

Table 7-5 shows the management goals for terrestrial and aquatic resources, attendant assessment endpoints, measures of effect, and decision rule by assessment endpoint number. Furthermore, the table provides definitions of Assessment Endpoints 1, 2, 3, and 4 (terrestrial receptors), and 5, 6, 7, and 8 (aquatic receptors). As stated, the assessment endpoint table includes a column about the conditions for making a decision depending on whether the HQ is less than or more than 1. If the HQ is greater than 1, the SMDP options from Ohio EPA/Army guidance are provided: no further action, risk management, monitoring, remediation, or further investigation. These are the logical options, and the options fitted to the RQL circumstances are provided in Section 7.5.

The assessment endpoints would be evaluated through the use of "measures" (formerly named measurement endpoints). EPA defines measures as ecological characteristics used to quantify and predict change in the assessment endpoints. They consist of measures of receptor and population characteristics,

Table 7-5. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for RQL During the Level II Screening

Management Goals	Assessment Endpoint	Measures of Effect	Decision Rule
Management Goal 1: The protection of terrestrial populations, communities, and ecosystems	Assessment Endpoint 1: Growth, survival, and reproduction of plant and soil invertebrate communities and tissue concentrations of contaminants low enough such that higher trophic levels that consume them are not at risk Receptors: plants and earthworms	Measures of Effect 1: Plant and earthworm soil toxicity benchmarks and measured RME concentrations of constituents in soil	Decision Rule for Assessment Endpoint 1: If HQs, defined as the ratios of COPEC RME concentrations in surface soil to TRV benchmarks for adverse effects on plants and soil invertebrates, are less than or equal to 1, then Assessment Endpoint 1 has been met and plants and soil-dwelling invertebrates are not at risk. If the HQs are >1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs and applicable media, or further investigation such as a Level III and Level IV Field Baseline
	Assessment Endpoint 2: Growth, survival, and reproduction of herbivorous mammal populations to low concentrations of contaminants in their tissues so that higher trophic level animals that consume them are not at risk Receptor: cottontail rabbits	Measures of Effect 2: Estimates of receptor home range area, body weights, feeding rates, and dietary composition based on published measurements of endpoint species or similar species; modeled COPEC concentrations in food chain based on measured concentrations in physical media; chronic dietary NOAELs applicable to wildlife receptors based on measured responses of similar species in laboratory studies	Decision Rule for Assessment Endpoint 2: If HQs, based on ratios of estimated exposure concentrations predicted from COPEC RME concentrations in surface soil to dietary limits corresponding to NOAEL TRV benchmarks for adverse effects on herbivorous mammals are less than or equal to 1, Assessment Endpoint 2 is met, and the receptors are not at risk. If the HQs are >1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline

Table 7-5. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the RQL During the Level II Screening (continued)

Management Goals	Assessment Endpoint	Measures of Effect	Decision Rule
Management Goal 1: The protection of terrestrial populations, communities, and ecosystems (continued)	Assessment Endpoint 3: Growth, survival, and reproduction of worm-eating and insectivorous mammal and bird populations and low enough concentrations of contaminants in their tissue so that predators that consume them are not at risk Receptors: shrews and robins	Measures of Effect 3: Estimates of receptor home range area, body weights, feeding rates, and dietary composition based on published measurements of endpoint species or similar species; modeled COPEC concentrations in food chain based on measured concentrations in physical media; chronic dietary NOAELs applicable to wildlife receptors based on measured responses of similar species in laboratory studies	Decision Rule for Assessment Endpoint 3: If HQs based on ratios of estimated exposure concentrations predicted from COPEC RME concentrations in surface soil to dietary limits corresponding to NOAEL TRV benchmarks for adverse effects on worm-eating and insectivorous mammals and birds is less than or equal to 1, then Assessment Endpoint 3 is met, and these receptors are not at risk. If the HQs are >1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline
	Assessment Endpoint 4: Growth, survival, and reproduction of carnivorous mammal and bird populations Receptors: red fox and red-tailed hawk	Measures of Effect 4: Estimates of receptor home range area, body weights, feeding rates, and dietary composition based on published measurements of endpoint species or similar species; modeled COPEC concentrations in food chain based on measured concentrations in physical media; chronic dietary NOAELs applicable to wildlife receptors based on measured responses of similar species in laboratory studies	Decision Rule for Assessment Endpoint 4: If HQs based on ratios of estimated exposure concentrations predicted from COPEC RME concentrations in surface soil to dietary limits corresponding to NOAEL TRV benchmarks for adverse effects on carnivorous mammals and birds are less than or equal to 1, then Assessment Endpoint 4 is met, and the receptors are not at risk. If the HQs are >1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline

Table 7-5. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the RQL During the Level II Screening (continued)

Management Goals	Assessment Endpoint	Measures of Effect	Decision Rule
Management Goal 2: The protection of aquatic populations, communities, and ecosystems	Assessment Endpoint 5: Survival, reproduction, and diversity of benthic invertebrate communities, as well as low enough concentrations of contaminants in their tissues so that higher trophic level animals that consume them are not at risk Receptor: benthic invertebrates	Measures of Effect 5: Measured concentration of contaminants in sediment and sediment toxicity thresholds, e.g., consensus-based TECs, EPA Region 5 ESLs, and Ohio EPA sediment reference values	Decision Rule for Assessment Endpoint 5: If HQs based on ratios of COPEC RME concentrations in sediment-to-sediment toxicity benchmarks are less than or equal to1, then Assessment Endpoint 5 is met and sediment-dwelling organisms are not at risk. If the HQs are > 1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline
	Assessment Endpoint 6: Growth, survival, and reproduction of aquatic biota (including fish, plants, invertebrates) Receptor: aquatic biota	Measures of Effect 6: Measured concentrations of contaminants in surface water and Ohio EPA Chemical-Specific Water Quality Criteria found in OAC 3745	Decision Rule for Assessment Endpoint 6: If HQs based on ratios of COPEC RME concentrations in surface water to aquatic biota toxicity benchmarks are less than or equal to 1, then Assessment Endpoint 6 is met and the receptors are not at risk. If the HQs are > 1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological resources, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline

Table 7-5. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the RQL During the Level II Screening (continued)

Management Goals	Assessment Endpoint	Measures of Effect	Decision Rule
Management Goal 2: The protection of aquatic populations, communities, and ecosystems (continued)	Assessment Endpoint 7: Growth, survival, and reproduction of aquatic herbivores that ingest aquatic plants, surface water, and sediment Receptors: muskrats and mallards	Measures of Effect 7: Estimates of receptor home range area, body weights, feeding rates, and dietary composition based on published measurements of endpoint species or similar species; modeled COPEC concentrations in food chain based on measured concentrations in physical media; chronic dietary NOAELs applicable to wildlife receptors based on measured responses of similar species in laboratory studies	Decision Rule 7: If HQs based on ratios of COPEC RME concentrations in surface water and sediment to dietary limits corresponding to NOAEL TRV benchmarks for adverse effects on aquatic herbivorous mammals and birds are less than or equal to 1, then Assessment Endpoint 7 is met and the receptors are not at risk. If the HQs are > 1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological receptors, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline
	Assessment Endpoint 8: Growth, survival, and reproduction of riparian carnivorous mammal and bird communities that feed on aquatic organisms Receptors: mink and herons	Measures of Effect 8: Estimates of receptor home range area, body weights, feeding rates, and dietary composition based on published measurements of endpoint species or similar species; modeled COPEC concentrations in food chain based on measured concentrations in physical media; chronic dietary NOAELs applicable to wildlife receptors based on measured responses of similar species in laboratory studies	Decision Rule 8: If HQs based on ratios of estimated exposure concentrations predicted from COPEC RME concentrations in surface water to dietary limits corresponding to NOAEL TRV benchmarks for adverse effects on riparian carnivores is less than or equal to 1, then Assessment Endpoint 8 has been met and these receptor populations are not at risk. If the HQs are > 1, a SMDP has been reached, at which it will be necessary to decide what is needed: no further action, risk management of ecological receptors, monitoring of the environment, remediation of any site-usage-related COPECs in applicable media, or further investigation such as a Level III and Level IV Field Baseline

COPEC = Constituent of potential concern.
EPA = U. S. Environmental Protection Agency.
ESL = Ecological screening level.
HQ = Hazard quotient.
NOAEL = No observed adverse effects level.
OAC = Ohio Administrative Code.
RQL = Ramsdell Quarry Landfill.
RME = Reasonable maximum exposure.
SMDP = Scientific management decision point.
TEC =Threshold effect concentration.
TRV = Toxicity reference value.

measures of exposure, and measures of effect. For example, measures of receptor characteristics include parameters such as home range, food intake rate, and dietary composition. Measures of exposure include attributes of the environment such as contaminant concentrations in soil, sediment, surface water, and biota. The measures of effect for the Level II Screen consist of the MDCs of each contaminant for soil or sediment (average concentrations for surface water) and ESV benchmarks for COIs in soil and sediment, as well as the Ohio state WQC for surface water (see Section 7.3.3).

Appropriate measures of exposure relating to the assessment endpoints for the Level II and Level III ERAs include measured concentrations of chemicals in surface soil, sediment, and surface water. Additional measures of exposure for the Level III Baseline would include predicted concentrations of chemicals in vegetation and various receptor animals such as rabbits, shrews, American robins, and aquatic biota based on measured soil, sediment, and surface water concentrations. The measures for the site-specific analysis screen and their relationship to their corresponding assessment endpoints are summarized above.

In the Level II Screen, MDCs in soil or sediment at each EU were compared to default soil or sediment concentrations that are expected not to cause harm to ecological populations. Average concentrations in surface water were compared to Ohio state WQC. The Level II screen used Ohio EPA (Ohio EPA 2003) published guidelines for selecting screening values for soil and sediment, and OAC WQC for surface water.

COPECs that remained after the Level II Screen are potentially subject to a Level III Baseline analysis with exposures that are more representative of the exposures expected for the representative receptors. Level III Baseline analysis includes evaluation of exposure of a variety of receptors to the reasonable maximum exposure concentrations of COPECs at each EU, using default dietary and uptake factors. The representative ecological receptors may not all be present at each EU. However, all representative receptors are evaluated at this step.

For the Level III Baseline, the decision rules for COPECs came from Ohio EPA's guidance for chemicals (Ohio EPA 2003). Briefly, for COPECs, the first decision rule is based on the ratio or HQ of the ambient exposure or EPC (numerator) of a given chemical to the ecological effects or toxicity reference value (denominator) of the same chemical. A ratio of 1 or smaller means that ecological risk is negligible while a ratio of greater than 1 means that ecological risk from that individual chemical is possible and that additional investigation should follow to confirm or refute this prediction. In addition, a sum of all the HQs (that is, the HI) for given groups of chemicals, (e.g., all inorganics, all organics, or all chemicals with a common mode of action) of 1 or less means that there is no concern, while a sum greater than 1 indicates that there may be a concern for that group of chemicals and that further investigation is needed. The second decision rule is that if "no other observed significant adverse effects on the health or viability of the local individuals or populations of species are identified" (Ohio EPA 2003) and the HI does not exceed 1, "the site is highly unlikely to present significant risks to endpoint species" (Ohio EPA 2003). There are three potential outcomes for the Level III Baseline: (1) no significant risks to endpoint species so no further analysis is needed, (2) conduct field baseline assessment to quantify adverse effects to populations of representative species that were shown to be potentially impacted based on hazard calculations in the Level III BERA, or (3) remedial action taken without further study.

7.5 RECOMMENDATION

Because this Level II SERA identified multiple COPECs in multiple abiotic media (surface soil, sediment, and surface water), and identified site-specific receptors and the presence of relevant and complete exposure pathways for those receptors, the potential exists for ecological hazard so a recommendation is made to move to a SMDP. The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in the assessment endpoint table (Table 7-5), are as follows:

1. Risk management of the ecological resources, although they are limited and include a poor quality wetland, as shown by applying the Ohio rapid wetland habitat assessment at RQL.

2. Remediation of some of the source material if land use (assumed to be military restricted access with no digging) and other evidence, such as site-related usage COPECs, really warrant it.

3. Conduct of more investigation, such as a Level III ERA, to further define COPECs when this would truly yield needed information to make a significantly better decision about the present and future role of ecological resources at RQL.

Note that other logical outcomes mentioned in the assessment endpoint table are not recommended:

4. No further action because of the presence of ecological risk.

5. Monitoring because of the need to make other decisions (1, 2, or 3) prior to this.

A WOE approach to the COPECs involved at RQL would assist in defining the best outcome or decision. The WOE would use such topics as (a) military land-use; (b) poor quality wetland habitat assessment at RQL (from the Ohio rapid wetland assessment); (c) useful findings of the ecological screening level work; (d) degree of correlation of site usage or suspected usage COPECs (from Step 4 of the RVAAP facility-wide ecological risk work plan); (e) negative consequences of source removal likely be more damaging to the habitat than status quo or current conditions; and (f) other, including the need or lack of need for ecological RGOs. The WOE will be part of the FS.

7.6 SUMMARY

The RQL site contains sufficient terrestrial and aquatic (soil, sediment, and surface water) habitat to support various classes of ecological receptors. For example, terrestrial habitats at RQL include old fields, woodlots, and grassy areas. Various classes of receptors, such as vegetation, small and large mammals, and birds, have been observed at the site. The presence of suitable habitat and observed receptors at the site warrants a SERA. Thus, Ohio EPA protocol (Level I) was met and Level II was needed.

A Level II SERA was performed for RQL soils, sediment, and surface water using Ohio EPA guidance methods. The Level II Screen consisted of a media-specific data and media evaluation of detected COIs, as well as a media-specific media screen. The data and media evaluation was conducted to identify whether the chemicals could be initially eliminated from further consideration due to low frequency of detection (data evaluation) and whether the chemicals were site related and have impacted the site [media evaluation that included comparison of detected concentrations against background (and SRVs for sediment) and identification of PBT compounds]. Any input COIs that were not eliminated during the data and media evaluation were carried forward to the media screen. The media screen entailed comparing concentrations of inputted chemicals against ESVs (for soil and sediment) and OAC WQS for surface water. Chemicals whose concentrations exceeded or lacked the ESVs or OAC WQS, as well as chemicals that were PBT compounds, were retained as COPECs while all other chemicals were eliminated from further action.

For surface soil, 56 detected COIs were inputted into the data and media evaluations, wherein 1 was eliminated due to low frequency of detection and not being a PBT compound, and 55 were identified as

COPECs and carried forward to the media screening. Of the 55 COPECs inputted into the media screening, 7 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 48 chemicals were retained as COPECs for surface soil.

For sediment, 40 detected COIs were inputted into the data and media evaluations, wherein 7 were eliminated because their concentrations either were less than the Ohio EPA SRVs or background and they were not PBT compounds. Thus, 33 of the 40 detected COIs were identified as COPECs and carried forward to the media screening. Of the 33 COPECs inputted into the media screening, only 3 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 30 chemicals were retained as COPECs for sediment.

For surface water, 28 detected COIs were inputted into the data and media evaluations, wherein 1 was eliminated due its concentration being less than background and not being a PBT compound. Thus, 27 of the 28 detected COIs were identified as COPECs and carried forward to the media screening. Of the 27 COPECs inputted into the media screening, 10 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 17 chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for soil, sediment, and surface water, ecological CSMs were prepared, along with the identification of site-specific ecological receptors, relevant and complete exposure pathways, and candidate assessment endpoints. These types of information will be used to prepare a Level III Baseline if it is deemed necessary to conduct a Level III ERA.

Based on the presence of multiple COPECs in soil, sediment, and surface water, as well as the presence of site-specific ecological receptors and complete exposure pathways to those COPECs at the RQL site, a recommendation is made to move to a SMDP. The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in Table 7-5 and Section 7.5, are: (1) risk management of the ecological resources, (2) remediation of some of the source material, or (3) conduct of more investigation. In the FS, a WOE approach to the COPECs involved at RQL would assist in defining the best outcome or decision. Thus, the information in this Level II SERA can be used to assist risk managers in making their decision associated with the SMDP.

8.0 SUMMARY AND CONCLUSIONS

The RQL Phase I RI Report presents a detailed analysis of the environmental data collected during the Phase I RI field effort. The following sections present an overview of the major findings of the nature and extent of contamination, modeling of contaminant fate and transport, and human health and ecological risk assessments. A revised CSM, combining Phase I RI information with previous Groundwater Investigation data, is presented to integrate results of all site assessment performed to date at the AOC. The CSM denotes, based on available data, where source areas occur, the mechanisms for contaminant migration from source areas to receptor media (e.g., streams and groundwater), and exit pathways from the AOC. The conclusions of the Phase I RI are presented by media, with an emphasis on the degree of contamination and the potential risks to human receptors.

8.1 SUMMARY

8.1.1 Contaminant Nature and Extent

The Phase I RI evaluated the nature and extent of contamination in surface soil from 0 to 1 ft bgs in the quarry bottom, in both discrete and multi-increment samples, and groundwater.

8.1.1.1 Data aggregates/EUs and data reduction

Surface soil and groundwater were evaluated on an AOC-wide basis. Summary statistics for data were calculated for the purposes of identifying SRCs. SRCs were identified by screening data against frequency of detection criteria, essential human nutrient criteria, and RVAAP facility-wide background values for inorganics. The nature and extent evaluation focused on only those constituents identified as site-related.

8.1.1.2 Surface soil

A total of ten surface soil samples from 0- to 0.3-m (0- to 1-ft) depth were collected for the purpose of determining nature and extent of surface soil contamination across Ramsdell Quarry. All discrete samples were analyzed for explosives, TAL metals, cyanide, and SVOCs; two discrete samples were analyzed for propellants; one discrete sample was analyzed for VOCs and pesticides/PCBs. In addition, multi-increment samples were collected from five approximately equal areas in the bottom of the quarry, exclusive of the pond and landfill toe slope. Multi-increment samples were analyzed for explosives, TAL metals, cyanide, and SVOCs; one multi-increment sample was also analyzed for propellants and pesticides/PCBs.

Surface Soil Discrete Samples

Explosives and propellants were detected at four discrete surface soil sample sites, RQL-025, -026, -027 and -030. The number of detected explosives and concentrations were greater along the western portion of the quarry bottom near the toe slope of the landfill. Fourteen inorganic analytes were identified as SRCs, including antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, thallium, and zinc. Site RQL-026 in the northwest area of the quarry had the highest number of inorganics exceeding background concentrations (16 SRCs). The sites with the lowest number of metals exceeding background concentrations were RQL-025 (4 SRCs) in the northern area of the site and RQL-032 (5 SRCs) in the southern area of the site. A total of 20 different SVOCs were detected and

SVOCs were detected at all sites. The MDCs for nearly all SVOCs were observed at RQL-026 in the northwest corner of the area. No VOCs, pesticides, or PCBs were detected.

Surface Soil Multi-increment Samples

Inorganic constituents were detected at all sites. The number of constituents that exceeded background concentrations ranged from 8 to 12, with antimony, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver, and zinc all frequently observed above background. SVOCs were detected in each multi-increment sampling area, except RQL-038. The number of SVOCs detected ranged from 11 to 15. The maximum concentrations for nearly all analytes were observed in sample RQL-034. No explosives, propellants, pesticides, PCBs, or VOCs were detected.

8.1.1.3 Groundwater

Six new groundwater wells were installed and sampled during the Phase I investigation. A total of 12 metals were identified as SRCs, including aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc. The sample collected from well RQLmw-013 had the highest number of inorganic SRCs (ten) followed by RQLmw-012 (nine). The well with the fewest identified SRCs (five) was RQLmw-014, which is the farthest downgradient well. The VOC carbon disulfide was detected at all six sites and is considered to be a SRC. No explosives, SVOCs, pesticides, or PCBs were detected in groundwater in any of the Phase I wells. The absence of explosives in Phase I RI wells downgradient of Ramsdell Quarry indicates that the maximum horizontal extent of contaminant migration has been defined. The absence of explosives in wells RQLmw-017 and -016, upgradient of RQL, indicate that explosives detected during the previous Groundwater Investigation in well RQLmw-006 were not sourced from Load Line 1.

8.1.2 Contaminant Fate and Transport

Based on site characterization and monitoring data, explosives, metals, and organics exist in the surface soil at Ramsdell Quarry. Fate and transport modeling using the quarry bottom as the selected source indicate that some of these contaminants may leach from contaminated soils into the groundwater beneath the source. Migration of many of the constituents, however, is likely to be attenuated because of moderate to high retardation factors. Currently, explosives, SVOCs, pesticides, and PCBs have not been detected in RQL groundwater samples. Based on screening of surface soil data against GSSLs, 1,3-DNB; 2,4-DNT; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; cadmium; chromium; mercury; nickel; thallium; 2-methylnaphthalene; carbazole; and dibenzofuran were identified as initial CMCOPCs.

SESOIL Modeling

1,3-DNB; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; chromium; and carbazole were identified as final CMCOPCs for Ramsdell Quarry based on source loading predicted by the SESOIL modeling. Manganese was observed to exceed its RBC (EPA Region 9 PRG) beneath the quarry and was identified as a final CMCOPC.

AT123D Modeling

Nitroglycerin, RDX, and carbazole were identified as CMCOCs based on conservative AT123D modeling. The maximum groundwater concentrations of the constituents were predicted to exceed MCLs or RBCs at the receptor (Sand Creek) at the closest point downgradient of the source. However, monitoring results from Phase I RI wells RQLmw-012, -013, and -014, located immediately downgradient or side-gradient of the quarry, have not confirmed the presence of these constituents in groundwater.

8.1.3 Human Health Risk Evaluation

The HHRA was conducted to evaluate risks and hazards associated with contaminated media at Ramsdell Quarry. Risks and hazards were estimated for one representative receptor (Security Guard/Maintenance Worker) exposed to one medium (surface soil, from a depth interval of 0 to 1 ft bgs). Risks and hazards were also estimated for potential exposure to surface soil, groundwater, sediment, and surface water by four additional receptors [National Guard Trainee, Fire/Dust Suppression Worker, Hunter/Fisher, and Resident Subsistence Farmer (adult and child)]. The following steps were used to generate conclusions regarding human health risks and hazards associated with contaminated surface soil at Ramsdell Quarry.

- identification of COPCs,
- calculation of risks and hazards,
- identification of COCs, and
- calculation of RGOs.

One metal (arsenic) and eight SVOCs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, indeno(1,2,3-*cd*)pyrene, and carbazole] were identified as COCs in surface soil for the Security Guard/Maintenance Worker.

Risk-based RGOs were computed for all nine COCs at a TR of 10^{-5} and a THI of 1. The EPCs used in this HHRA for arsenic (15.3 mg/kg), benzo(*k*)fluoranthene (107 mg/kg), chrysene (185 mg/kg), and carbazole (84.9 mg/kg) were all smaller than their associated most conservative risk-based RGO (26; 129; 1,287; and 608 mg/kg, respectively) based on a TR of 10^{-5}. The EPC for arsenic (15.3 mg/kg) was also smaller than the surface soil background concentration for RVAAP (15.4 mg/kg). Surface soil EPCs were highly influenced by the results from one particular sample (RQL-026), as the MDCs for all eight organic COCs came from this one sample. For these eight organic COCs, the only sample location other than RQL-026 with a detected concentration larger than an RGO is RQL-025, where benzo(*a*)pyrene was detected at 6.8 mg/kg, which is above its RGO of 1.29 mg/kg.

While a Land Use Plan has been drafted for RTLS, as summarized in the FWHHRAM (USACE 2004b), and OHARNG will control the property, there is uncertainty in the details of the future land use (e.g., if the perimeter fence is not maintained, then a trespasser could enter the property or if hunting restrictions are relaxed, then a hunter could utilize the site). To address this uncertainty, additional receptors (e.g., Hunter/Fisher, National Guard Trainee, and Fire/Dust Suppression Worker) are included in the risk assessment. There is little to no uncertainty associated with the assumption that RVAAP will not be released for residential use; however, a Resident Subsistence Farmer receptor was evaluated to provide a baseline scenario to evaluate unrestricted release.

An additional two surface soil COCs are identified for the National Guard Trainee (chromium) and Resident Subsistence Farmer (2,6-dinitrotoluene) exposure scenarios.

The Security Guard/Maintenance Worker is not exposed to groundwater, sediment, or surface water. COCs identified for these media for the other receptors evaluated are listed below.

Two COCs (arsenic and manganese) were identified in groundwater.

Four COCs [arsenic, chromium, manganese, and benzo(*a*)pyrene] were identified in sediment.

Three COCs (arsenic, manganese, and aldrin) were identified in surface water.

8.1.4 Ecological Risk Evaluation

The Ramsdell Quarry site contains sufficient terrestrial and aquatic (soil, sediment, and surface water) habitat to support various classes of ecological receptors. For example, terrestrial habitats at Ramsdell Quarry include old fields, woodlots, and grassy areas. Various classes of receptors, such as vegetation, small and large mammals, and birds, have been observed at the site. The presence of suitable habitat and observed receptors at the site warranted a SERA. Thus, Ohio EPA protocol (Level I) was met and Level II was needed.

The Level II SERA performed for Ramsdell Quarry included soils, sediment, and surface water using Ohio EPA guidance methods. The Level II screen consisted of a media-specific data evaluation for detected COIs, as well as a media-specific screen. The data and media evaluation were conducted to identify whether the chemicals could be initially eliminated from further consideration due to low frequency of detection (data evaluation) and whether the chemicals were site related and have impacted the site [media evaluation that included comparison of detected concentrations against background (and SRVs for sediment) and identification of PBT compounds]. Any input COIs that were not eliminated during the data evaluation were carried forward to the media screen. The media screen entailed comparing concentrations of inputted chemicals against ESVs (for soil and sediment) and OAC WQS for surface water. Chemicals whose concentrations exceeded or lacked the ESVs or OAC WQS, as well as chemicals that were PBT compounds, were retained as COPECs while all other chemicals were eliminated from further action.

8.1.4.1 Soil

For surface soil, 56 detected COIs were inputted into the media-specific data evaluations, wherein one compound was eliminated due to low frequency of detection and by virtue of not being a PBT compound. The remaining 55 COIs were identified as COPECs and carried forward to the media screening. Of the 55 COPECs inputted into the media screening, 7 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds; thus, a total of 48 chemicals were retained as COPECs for surface soil.

8.1.4.2 Sediment and surface water

Sediment

For sediment, 40 detected COIs were inputted into the media-specific data evaluation, wherein 7 were eliminated because their concentrations either were less than the Ohio EPA SRVs or background and they were not PBT compounds. Thus, 33 of the 40 detected COIs were identified as COPECs and carried forward to the media screening. Of the 33 COPECs inputted into the media screening, only 3 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds; thus, a total of 30 chemicals were retained as COPECs for sediment.

Surface Water

For surface water, 28 detected COIs were inputted into the media-specific data evaluation, wherein 1 compound was eliminated due its concentration being less than background and it was not a PBT compound. Thus, 27 of the 28 detected COIs were identified as COPECs and carried forward to the media screening. Of the 27 COPECs inputted into the media screening, 10 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds; thus, a total of 17 chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for soil, sediment, and surface water, ecological CSMs were prepared, along with the identification of site-specific ecological receptors, relevant and complete exposure pathways, and candidate assessment endpoints. These types of information will be used to prepare a Level III baseline if it is deemed necessary to conduct a Level III ERA.

8.1.4.3 Conclusions

Based on the presence of multiple COPECs in soil, sediment, and surface water, as well as the presence of site-specific ecological receptors and complete exposure pathways to those COPECs at Ramsdell Quarry, a recommendation is made to move to a SMDP. The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in Chapter 7.0, are: (1) risk management of the ecological resources based on the military land use or other reasons that may include development of RGOs or WOE analysis that no RGOs are required; (2) remediation of some of the source material, if required, to reduce ecological risks; or (3) conduct of more investigation, such as a Level III. In the FS, a WOE approach to the COPECs involved at RQL would assist in defining the best outcome or decision. Thus, the information in the Level II SERA is presented to assist risk managers in making the decision to proceed with the SMDP.

8.2 CONCEPTUAL SITE MODEL

The preliminary Ramsdell Quarry CSM, developed as part of the Groundwater Investigation (USACE 2000), was summarized in Chapter 2.0. A revised CSM is presented that incorporates Phase I RI data and the results of contaminant fate and transport modeling and risk evaluations. Elements of the CSM include:

- primary contaminant source areas and release mechanisms,
- contaminant migration pathways and exit points, and
- data gaps and uncertainties.

An illustrated version of the revised CSM is provided in Figure 8-1 to assist in visualizing the concepts discussed below.

8.2.1 Source-Term and Release Mechanisms

Three potential source terms were evaluated as part of the CSM: the former landfill, soil and sediment within the bottom of the quarry, and Load Line 1.

Ramsdell Quarry Landfill

Available records for RQL indicate that only non-hazardous solid waste was disposed of between 1976 and 1989. No information regarding landfill disposal activities is available for the period of 1941 to 1976; however, based on operational history, it may be assumed that aerosol cans, paint residues, pesticide containers, materials contaminated with petroleum products (e.g., oil filters, rags, etc.), and various other typical heavy industrial facility wastes were likely placed into the landfill. Disposal of materials containing explosives or propellants residues is not known. As such, a wide variety of potential

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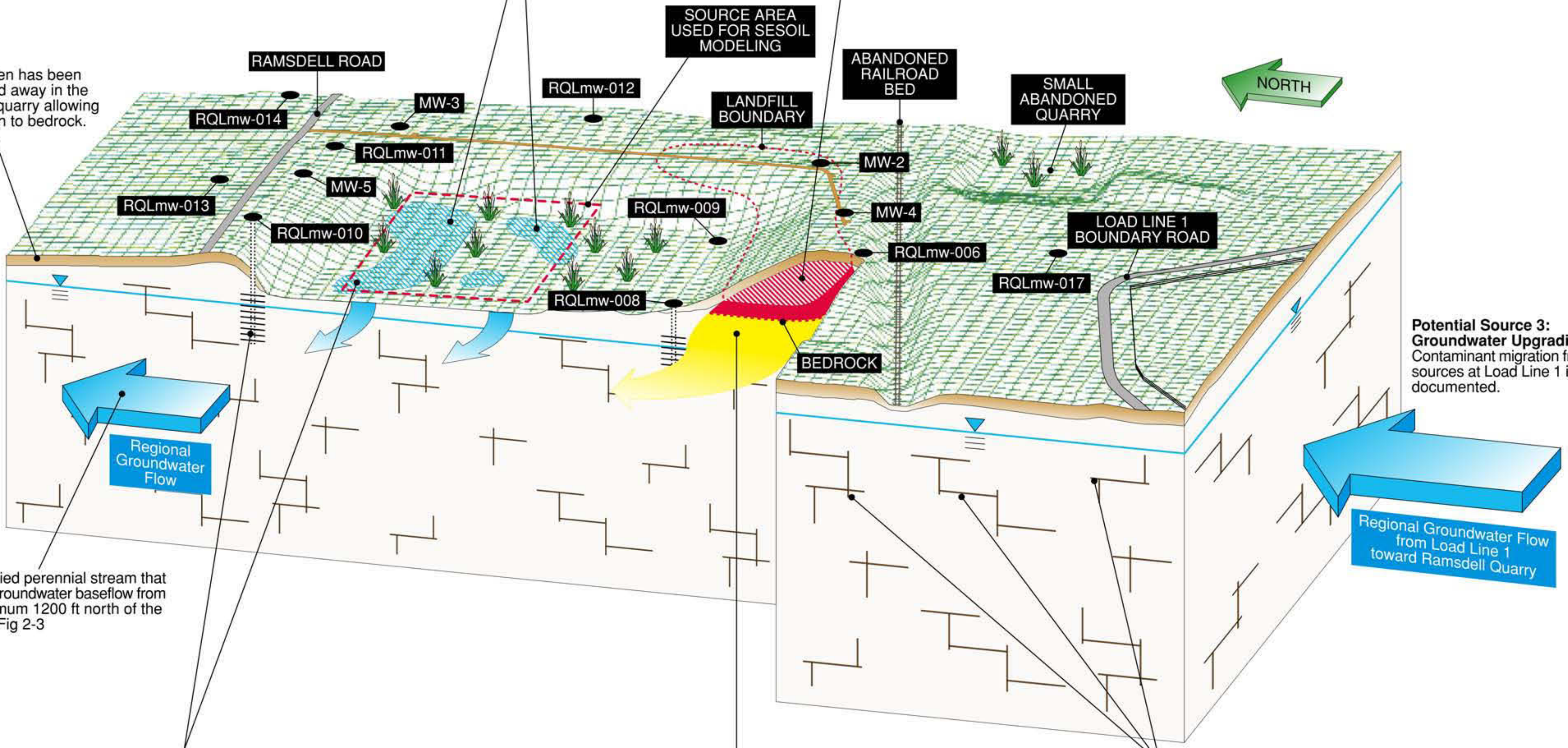
Potential Source 2: Soils and Sediment on Quarry Bottom
Quarry ponds act as recharge points during the wet season. Mounding of the water table during wet periods produces a flat potentiometric surface and temporary, short-term flow reversals in the water table interval. The ponds act as a potential sink during periods of dry weather due to evapotranspiration. Sediment layer in the pond may slightly retard infiltration. The HHRA identified one metal (arsenic) and eight SVOCs as surface soil COCs for the Security Guard/Maintenance worker (most likely scenario). The SERA identified forty-eight COPECs for surface soil, thirty COPECs for sediment, and seventeen COPECs for surface water.

Potential Source 1: Landfill
Nonhazardous solid wastes (hachured area) were placed in RQL between 1976 and 1989. Historical landfilled wastes containing explosives, metals, and possibly other organics (solid red) were placed between 1941 and 1976. Around 1980 to 1981 wastes within the bottom and north side of Ramsdell Quarry were removed. Historical wastes beneath RQL were not removed. During periods of high water table levels, historical wastes may be partially inundated, thereby enhancing leachate development.



Thin overburden has been largely stripped away in the bottom of the quarry allowing rapid infiltration to bedrock.

Potential Source 3: Groundwater Upgradient of RQL
Contaminant migration from upgradient sources at Load Line 1 is not presently documented.

Nearest identified perennial stream that could receive groundwater baseflow from RQL is a minimum 1200 ft north of the AOC (refer to Fig 2-3

Although the ponds are hydraulically connected to groundwater, quarry pond sediments do not appear to act as a significant secondary source of contaminants, with the potential exception of metals. Sediments contain explosives and PAHs. PAHs were never detected in groundwater. Explosives were not detected in RQLmw-010 and only detected once in RQLmw-011 and once in surface water.

Leaching from landfill contents contributes explosives, trace metals, and VOCs to shallow groundwater. Dispersion patterns and short-term flow reversals also impact upgradient well RQLmw-006. Lateral extent of explosives migration appears to be limited based on absence of contaminants in Phase I perimeter wells. Contamination has migrated to the vicinity of RQLmw-011 northeast of RQL. No seeps have been observed at the base of RQL and the soil/clay surface cover remains intact. The Security Guard/Maintenance Worker is not exposed to groundwater. Groundwater was not evaluated in the SERA.

Groundwater flow occurs predominantly through connected fractures bounding lower permeability blocks of bedrock matrix.

G05-0141 Ramsdell Quarry

Figure 8-1. Environmental Conceptual Site Model for Ramsdell Quarry

source-related contaminants may be present. RQL overlies bedrock, is unlined, and a leachate collection system was not installed or required as part of engineered controls. Closure did not involve the placement of an engineered cap and vent system over the landfill. Results of the Groundwater Investigation indicated that Ramsdell Quarry is a source term for metals, explosives, nitroglycerin, and trace levels of VOCs in groundwater within the AOC. It is difficult to discern whether the former landfill is the only source for these constituents because soil and sediment in the bottom of the quarry were also documented to contain contaminants above background levels. However, based on the distribution of contaminants within the AOC, the former landfill appears to be the most plausible source to groundwater and may also have contributed to observed contaminants in soil located near the toe slope of the landfill. The AOC does not appear to represent a source of SVOCs to groundwater based on available monitoring results. The primary release mechanism to groundwater likely includes infiltration of precipitation either through the soil cover layer or from upslope areas beneath the edge of the cap. Subsequently, leaching and migration of contaminants from landfilled wastes occurs through fractures in the bedrock vadose zone until intercepting the water table. Prior to landfill closure, surface water leaching and erosional transport processes also may have mobilized contaminants from primary waste materials, either in dissolved phase or particulate bound, and resulted in accumulation within sediment and surface soil in low-lying areas of the quarry.

Ramsdell Quarry was used for open burning of waste explosives and munitions, as well as annealing residues. Results of the investigations show that sediments and soil in the bottom of the quarry contain residual metals, cyanide, SVOCs, and explosive and propellant compounds. Review of signature contaminants in the quarry sediments (cyanide, PAHs, and explosives) does not provide conclusive evidence that they act as a secondary source term to groundwater. SESOIL model results suggest that sediment and soil in the bottom of the quarry may contribute metals, explosives, and carbazole to groundwater. Monitoring results, however, do not provide confirmation of the modeling predictions. Explosives were detected during the Groundwater Investigation on only one occasion in monitoring wells immediately downgradient of the quarry bottom (wells RQLmw-010 and -011), as compared to multiple detections in those wells located at the toe of the landfill slope (wells RQLmw-007, -008, and -009). In addition, PAHs were not detected in any AOC monitoring wells. The lack of explosives in Phase I RI groundwater monitoring wells indicates that the extent of explosives contamination related to Ramsdell Quarry is limited to the immediate vicinity of the AOC and has been defined by the monitoring network. Explosives, propellants, cyanide, and SVOCs were not detected in associated surface water samples during the Groundwater Investigation, indicating that contaminant mass transfer from sediment to surface water with subsequent infiltration of contaminated surface water is not a significant release mechanism.

Load Line 1, located approximately 800 ft to the south of Ramsdell Quarry, is a known source term for explosives, propellants, metals, and PCBs/pesticides. Available potentiometric data indicate that the northern portion of the load line is hydraulically upgradient to RQL; thus, groundwater flow toward Ramsdell Quarry is possible via fracture pathways. Data obtained during the course of Phases I and II RI activities at Load Line 1 show that the northernmost well at Load Line 1 did not contain signature contaminants (i.e., explosives) above detectable levels. Additionally, the lack of explosives in upgradient wells RQLmw-017 and -016 at Ramsdell Quarry indicate that Load Line 1 is not the source for explosives previously observed in well RQLmw-006 during the Groundwater Investigation. The probability of attenuation and dilution within the shallow, active groundwater flow pathways is high, which would likely preclude long-distance migration of explosives and propellants from contaminated areas in Load Line 1 to Ramsdell Quarry. High adsorption coefficients for inorganic constituents also preclude long distance transport from Load Line 1 to Ramsdell Quarry. On this basis, Load Line 1 is not currently believed to impact groundwater quality at RQL.

8.2.2 Groundwater Flow and Contaminant Migration Pathways

A majority of groundwater flow at Ramsdell Quarry occurs through permeable fracture pathways within bedrock. The overburden layer in the site vicinity is characteristically thin and has been largely removed within the quarry by past operations; therefore, infiltration occurs almost directly to bedrock. Previous studies indicate rapid, strong potentiometric response to storm events.

Potentiometric data show that horizontal hydraulic gradients are consistently to the northeast. Studies to date show that the quarry pond is a static representation of the water table and may even function as a sink through evapotranspiration processes. During the wet season of the year, a sufficient reservoir of water exists in the quarry pond to act as a recharge point to groundwater. As a result, potentiometric surface elevations in upgradient well RQLmw-006 and those at the toe of the landfill are essentially equal. Rainfall events during the wet period of the year provide additional volume to the quarry pond and produce sufficient hydraulic head to produce slight, localized flow gradient reversals between the pond and well RQLmw-006 for short periods of time. Continuous potentiometric data are not available to determine whether this effect extends as far south as well RQLmw-017; however, the lack of detectable explosives in this well indicates that it does not. Wells RQLmw-010 and -011 remain consistently downgradient of RQL throughout the year based on previous studies, and Phase I RI monitoring wells RQLmw-012, -013, and -014 confirm a northeasterly flow direction.

The distribution of contaminants in wells at RQL are consistent with the observed hydraulic characteristics. Considering that the horizontal potentiometric gradient is flat and exhibits localized short-term reversals, leaching from RQL is the likely source of observed contaminants in well RQLmw-006. For a majority of the year, groundwater flow is consistently to the north-northeast providing the mechanism for contaminant migration to wells located at the toe of the former landfill and to RQLmw-011. The nearest identified receptor stream that could receive groundwater baseflow from the RQL vicinity is a minimum of 1,200 ft to the north of the AOC (refer to Figure 2-3). No data have been collected to date to indicate that groundwater would potentially discharge to this tributary. Phase I RI monitoring data indicate that the distribution of contamination is limited to the immediate vicinity of the AOC.

8.2.3 Uncertainties

The CSM is developed based on available site characterization and chemical data. The CSM is subject to inherent uncertainties depending on the density and availability of data. Inherent uncertainties in the CSM for Ramsdell Quarry include:

- Incomplete operational records and source term characterization exist for the former landfill. The landfill is assumed to be the primary source for groundwater contaminants, such as explosives, propellants, and VOCs. However, soil and sediment in the bottom of the quarry also contained contaminants above background levels and distinguishing between the two potential sources is subject to uncertainty.

- The Phase I RI monitoring network indicates that the maximum extent of groundwater contamination associated with the AOC has been defined. However, it is recognized that groundwater flow occurs through discrete fractures within the bedrock and that the monitoring network likely does not intercept all possible flow pathways.

8.3 CONCLUSIONS

The conclusions presented below, by medium, combine the findings of the contaminant nature and extent evaluation, fate and transport modeling, and the human health and ecological risk evaluations. To support remedial alternative selection and evaluation in future CERCLA documents (e.g., FS), RGOs were developed for identified COCs in surface soil, groundwater, sediment, and surface water at Ramsdell Quarry at an HI of 1 or risk level of 10^{-5}.

8.3.1 Surface Soil

Explosives, metals, and SVOCs were detected above background in surface soil samples at RQL. Fate and transport modeling or monitoring data indicate that 1,3-DNB; 2,6-DNT; nitroglycerin; RDX; antimony; arsenic; chromium; manganese; and carbazole may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs. Of these CMCOPCs, nitroglycerin, RDX, and carbazole were predicted, based on AT123D modeling, to potentially exceed MCLs or RBCs at Sand Creek at the closest point downgradient of the AOC. Monitoring results from the Phase I RI do not indicate that such migration is occurring beyond the immediate vicinity of the AOC.

One metal (arsenic), seven PAHs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenz(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene], and one SVOC (carbazole) were identified as COCs in surface soil for the Security Guard/Maintenance Worker. The EPCs for arsenic, benzo(*k*)fluoranthene, chrysene, and carbazole were all smaller than their most conservative RGO at a TR of 10^{-5}. The EPC for arsenic (15.3 mg/kg) was also smaller than the surface soil background concentration for RVAAP (15.4 mg/kg). Detected concentrations for all eight organic COCs at station RQL-026 exceeded RGOs. The only other Phase I RI sample location with a detected concentration greater than an RGO was station RQL-025 (benzo(*a*)pyrene.

An additional two surface soil COCs are identified for the National Guard Trainee (chromium) and Resident Subsistence Farmer (2,6-dinitrotoluene) exposure scenarios.

Forty-eight chemicals were retained as COPECs for surface soil based on the Level I and II SERA. Site-specific ecological receptors, relevant and complete exposure pathways, and candidate assessment endpoints were also identified.

8.3.2 Groundwater

Detected concentrations of metals above background criteria occur throughout Phase I groundwater wells at RQL; however, only three metals (arsenic, lead, and manganese) were found to exceed Region 9 PRGs The MDCs of arsenic and lead were well below Ohio MCLs and federal treatment standards. Carbon disulfide was detected in all six wells during the Phase I RI; however, this constituent is believed to be an analytical artifact based on its distribution. Furthermore, carbon disulfide was not detected in any wells during a subsequent wet season sampling event conducted in May 2004. Explosives, SVOCs, pesticides, and PCBs have not been detected in groundwater at RQL to date.

The Security Guard/Maintenance Worker is not exposed to groundwater. Two COCs (arsenic and manganese) were identified in groundwater for the other receptors evaluated.

Sediment and Surface Water

The Security Guard/Maintenance Worker is not exposed to sediment or surface water. COCs identified for these media for the other receptors evaluated are listed below.

- Four COCs [arsenic, chromium, manganese, and benzo(*a*)pyrene] were identified in sediment.
- Three COCs (arsenic, manganese, and aldrin) were identified in surface water.

8.4 LESSONS LEARNED

A key project quality objective for the Phase I RI at Ramsdell Quarry is to document lessons learned so that future projects may benefit from lessons learned and constantly improve data quality and performance. Lessons learned are derived from process improvements that were implemented or corrective measures for nonconformances.

- The presence of Ohio EPA and USACE staff on-site during field operations was beneficial in that potential changes to the project work plan due to field conditions could be quickly discussed, resolved, and implemented.

- The availability of on-site facilities for use as a field staging area and to house the field explosives laboratory was extremely beneficial. Having high-quality shelter facilities for sample storage and management operations, equipment decontamination, and the field laboratory improves sample quality and project efficiency. The facility provides a central and secure location to store equipment and supplies, as well as to conduct safety meetings and other site-specific training.

- Future planned well plugging and abandonment efforts should include compilation of detailed well construction information during the project scoping phase to the extent that such records are available. Field inspection of the wells to be plugged and abandoned, including sounding of well depths, is recommended to verify casing types and diameters and well depths. Such information will allow project teams to prepare and mobilize the necessary equipment to complete the plugging and abandonment task with as little downtime as possible due to unforeseen field conditions.

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9.0 RECOMMENDATIONS

To provide decision makers with the information necessary to evaluate remedial alternatives to reduce or eliminate potential risks to human and/or ecological receptors, it is recommended that Ramsdell Quarry proceed to the FS phase under the RVAAP CERCLA process. It is recommended that the FS phase employ a streamlined remedial alternatives evaluation process based on the most likely land use assumptions and evaluate a focused set of technologies, alternatives, and associated costs based on the most likely foreseeable land use. The intent of this strategy is to accelerate response complete or response in place for the AOC by focusing the FS efforts to appropriate remedies based on site conditions and land use considerations. Ramsdell Quarry is an ideal candidate for a focused FS approach because of the limited extent of contamination and the presence of the landfill would effectively preclude most, if not all, land uses other than maintenance and monitoring. For surface water and groundwater, the FS for Ramsdell Quarry should recognize and defer, if appropriate, to the separate facility-wide investigations for these integrator media.

Additional characterization of the AOC is not necessary, based on data obtained to date, to proceed with the FS phase. Substantial data gaps have not been identified following completion of the Groundwater Investigation and Phase I RI. Long-term monitoring and reporting in compliance with Ohio solid waste regulations is anticipated to continue and should be considered when developing the path forward under the FS.

The future land uses and controls envisioned for Ramsdell Quarry should be determined prior to selection of the path forward for the site. Establishment of the most likely land use scenario(s) will allow decision makers the initial information necessary to determine the correct remedial action land use controls, and/or continued monitoring, to achieve requisite protection of human health and the environment. The envisioned future use of the AOC, or a portion of the AOC, is an important consideration in determining the extent of remediation necessary to achieve the required degree of protectiveness. For example, a Security Guard/Maintenance Worker land use scenario versus a National Guard Trainee scenario influences how much cleanup is needed to lower the risk to protective levels. Establishment of land use will also allow for streamlined evaluation of remedies and will be necessary for documentation in a Record of Decision, as applicable. Based on land use considerations, risk managers should identify the need for any additional human health risk evaluation or RGO development and whether further evaluation of ecological risks, as denoted in Chapter 7.0, may be required, or if ecological RGOs are required for the AOC.

Monitoring wells MW-1 through MW-5 are non-specification wells installed with long open intervals in the bedrock zone. The open intervals were largely backfilled prior to installing screens and casings. These long open boreholes represent potential pathways for movement of contaminants from fracture pathways in shallow bedrock intervals to deeper groundwater intervals. It is recommended that plugging and abandonment of these wells be completed upon availability of funding.

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APPENDIX A

SOIL SAMPLING LOGS

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APPENDIX B

MONITORING WELL INSTALLATION AND DEVELOPMENT LOGS

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APPENDIX C

MONITORING WELL SAMPLING LOGS

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APPENDIX D

SLUG TEST LOGS AND SOLUTIONS

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APPENDIX E

PROJECT QUALITY ASSURANCE SUMMARY

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APPENDIX F

DATA QUALITY CONTROL SUMMARY REPORT

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APPENDIX G

LABORATORY ANALYTICAL RESULTS

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FATE AND TRANSPORT MODELING RESULTS

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APPENDIX I

TOPOGRAPHIC SURVEY REPORT

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APPENDIX J

ORDNANCE AND EXPLOSIVES AVOIDANCE SURVEY REPORT

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APPENDIX K

INVESTIGATION-DERIVED WASTE MANAGEMENT REPORTS

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APPENDIX L

HUMAN HEALTH RISK ASSESSMENT TABLES AND FIGURES

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APPENDIX M

ECOLOGICAL RISK ASSESSMENT DATA

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