FINAL

PHASE II
REMEDIAL INVESTIGATION REPORT

FOR

ERIE BURNING GROUNDS (RVAAP-02) 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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Prepared by

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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 II Remedial Investigation for Erie Burning Grounds (RVAAP-02) 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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ACRONYMS

ADD	average daily dose
ALM	Adult Lead Methodology
amsl	above mean sea level
AOC	area of concern
AT123D	Analytical Transient 1-, 2- ,3-Dimensional model
AUF	area use factor
BAF	bioaccumulation factor
BCF	bioconcentration factor
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
COEC	chemical of ecological 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
DNT	dinitrotoluene
DQA	data quality assessment
DQO	data quality objective
EBG	Erie Burning Grounds
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
FCM	food chain multiplier
FS	feasibility study
FWHHRAM	*Facility-wide Human Health Risk Assessor Manual*
GAF	gastrointestinal absorption factor
GPL	GPL Environmental, 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 (model)

ILCR	incremental lifetime cancer risk
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
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
MOA	Memorandum of Agreement
NEPA	National Environmental Policy Act
NFA	no further action
NGB	National Guard Bureau
NOAEL	no observed adverse effect level
NWI	National Wetlands Inventory
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ODOW	Ohio Department of Wildlife
OE	ordnance and explosive
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
ppm	parts per million
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
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
TCE	trichloroethene
TEF	toxicity equivalency factor
THI	target hazard index
TNB	trinitrobenzene
TNC	The Nature Conservancy
TNT	trinitrotoluene
TOC	total organic carbon
TR	target risk
TRV	toxicity reference value
TUF	temporal use factor
UCL_{95}	95% upper confidence limit
USACE	U. S. Army Corps of Engineers
USCS	Unified Soil Classification System
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 II 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 Erie Burning Grounds (EBG) at the Ravenna Army Ammunition Plant (RVAAP) in Ravenna, Ohio. This Phase II RI was conducted under subcontract to the U. S. Army Corps of Engineers (USACE), Louisville District for the RVAAP Installation Restoration Program.

The scope of this investigation is to determine the extent of contamination in affected media (soils, sediments, surface water, and groundwater) identified during the Phase I RI at EBG. The primary project objectives for the Phase II RI of EBG are as follows:

- Assess the presence or absence and map the extent of area of concern (AOC)-related contaminants in the uppermost groundwater interval.
- Conduct limited surface soil sampling of the western portion of the Track 49 embankment, the area south of the east leg of the T-Area, and the northwestern wooded area to complete the evaluation of contaminant nature and extent.
- Conduct sediment and surface water sampling at selected locations to delineate the extent of contaminants downstream of EGB, identify if any contaminant flux is occurring from upstream sources, and evaluate temporal trends in contaminated media identified during the Phase I RI.
- Conduct human health and ecological risk evaluations and develop human health risk-based remedial goal options (RGOs) for use in determining areas that may require remediation and in evaluating remedial alternatives in a subsequent feasibility study (FS).
- Update AOC site characteristics and refine the conceptual site model (CSM) based on groundwater information collected during the Phase II RI.
- Assess any remaining data gaps with respect to sources and extent of soil, sediment, and surface water contamination identified during the Phase I and II RIs and provide recommendations for a path forward for the AOC.

PREVIOUS INVESTIGATIONS

Three historical investigations have been conducted at EBG: (1) Soil and Sediment Analyses, RVAAP (Mogul Corporation 1982); (2) Water Quality Surveillance Program (USATHAMA 1980-1992); and (3) Relative Risk Site Evaluation (USACHPPM 1996). Additionally, a Phase I RI for EBG was conducted in 1999 (USACE 2001c).

Historical investigations included limited sampling and are summarized in the EBG Phase I RI Report. The Phase I RI included collection of surface soil, subsurface soil samples, sediment, and surface water samples (USACE 2001c). Results indicate levels of explosive, organic, and inorganic constituents above human health and ecological risk evaluation screening levels in soil, sediment, and surface water. The Phase I RI did not include an assessment of the AOC groundwater. Additional characterization and human health and ecological risk evaluations were recommended under the auspices of a Phase II RI.

AVAILABLE DATA

EBG remained relatively undisturbed between the Phase I and Phase II RIs. Therefore, soil and sediment data were assumed to still be representative of current site conditions and are included in the Phase II risk evaluations. Phase I and II RI surface water data were also evaluated in the risk evaluations to represent the full range of potential site conditions that may exist within the AOC (e.g., dry conditions, low pool levels, normal precipitation conditions, and high pool levels).

The data collected under this Phase II RI include:

- ten discrete surface soil samples [0 to 1 ft below ground surface (bgs)];
- five multi-increment surface soil samples (0 to 1 ft bgs);
- seven discrete sediment samples (0 to 0.5 ft bgs);
- triplicate multi-increment sediment samples from two different sampling area (six total samples, 0 to 0.5 ft bgs);
- eight surface water samples (six co-located with sediment samples); and
- eight 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 samples were analyzed for explosives, target analyte list metals, cyanide, and semivolatile organic compounds (SVOCs). Three discrete surface soil samples were analyzed for propellants and two discrete samples were analyzed for pesticides/polychlorinated biphenyls (PCBs) and volatile organic compounds (VOCs). Explosives site-related contaminants (SRCs) were detected along the north and south embankment of Track 49. Four new explosive SRCs were detected in the Phase II soils [2,6-dinitrotoluene (DNT); 2-amino-4,6-DNT; 4-amino-2,6-DNT; and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)]. No explosives were found in the wooded area in the northwest portion of the AOC. Inorganic SRCs included between 10 and 14 metals in each of the Phase II stations on the north and south sides of Track 49 embankment. With the exception of cadmium, metals were not present above background in the wooded area in the northwest or southeast portions of the AOC. PCB compounds were not detected in Phase II RI (or Phase I RI) surface soil samples.

Surface Soil Multi-increment Samples

Multi-increment soil samples were collected from five separate areas at EBG. Explosives were detected at one multi-increment sample location from the north Track 49 embankment area. Between 2 and 14 inorganic constituents were identified above background in the multi-increment sample areas, with sample EBG-144 (south) containing 11 SRCs, and EBG-143 (north) containing 9 SRCs. At least one, and as many as 12, SVOCs were detected in four of the five multi-increment samples collected. SVOCs were not detected in EBG-144, on the south of the embankment. The greatest number of SVOCs was also observed in the multi-increment sample from the north Track 49 embankment. Seven SVOCs were detected at EBG-142, located in the vicinity of the Former Borrow Area.

Sediment Samples

Explosives or propellants in sediments were detected at the north inlet (nitrobenzene), and in the former drainage channel in the south basin (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine). Explosives were not detected in the sediment samples collected downstream of the EBG outlet. Inorganic SRCs were observed at the north and east inlets, the former drainage channel in the south basin, and downstream of the EBG outlet. The SVOC bis(2-ethylhexyl)phthalate was detected in five of six sediment samples, and the polycyclic aromatic hydrocarbon (PAH) fluoranthene was detected downstream of the EBG outlet. SVOCs were not detected in the surface water basins or beyond the AOC boundary in the Phase I investigation. VOCs were also detected at the EBG outlet and stations downstream. PCBs were not detected in Phase II RI samples. The pesticide methoxychlor was detected in the Phase II RI sediment sample from the former drainage channel in the south basin.

Sediment Multi-increment Samples

Three multi-increment samples were collected from each of two multi-increment sampling areas, one located in the north basin, and one in the south basin along the axis of the former drainage channel. The north basin multi-increment samples displayed better reproducibility of results than the south basin samples. With the exception of pesticides, all three samples from the north basin had similar constituents and concentrations. Notably, only one of the three south basin samples had detections of explosives. Overall, explosives, metals, SVOCs, and pesticides were all more prevalent in the north basin multi-increment samples than in the south basin multi-increment samples.

Surface Water Samples

Explosive compounds were not detected at the eight surface water stations sampled during the Phase II RI. The propellant nitrocellulose was detected in the Phase II surface water sample collected from the east inlet. A total of seven metals were detected above background criteria at least once in Phase II surface water samples, including antimony, beryllium, cadmium, cobalt, lead, nickel, and vanadium. The background criterion for all seven metals is zero, as they were not detected in the background data set. As was seen for Phase II sediment, the greatest number of metals above background occurred in the sample collected from the former drainage channel in the south basin. This area was identified as having only minor contamination in the Phase I RI. Metals were detected above background at the EBG outlet (EBG-157) and stations immediately downstream (EBG-158 and -159), as well as the off-AOC location (EBG-161) at PF534. The off-AOC sample point (EBG-161) at PF534 also contained inorganic SRCs above background criteria during the Phase I RI. SVOCs, pesticides, and PCBs were not detected in Phase II surface water samples. The Phase II RI samples had detectable VOCs for samples collected in the T-Area and at the east inlet, which was also noted in the Phase I RI, and at EBG-161 located at PF534. VOCs had not been detected previously at the PF534 location. The VOCs most frequently detected in the Phase I (acetone, toluene, carbon disulfide) were not detected in Phase II samples. PCBs were not detected in either the Phase I or II RIs.

Groundwater

Explosives were not detected in any of the groundwater wells installed and sampled during the Phase II RI. Nine inorganic SRCs were detected in at least one of the eight EBG monitoring wells (antimony, arsenic, barium, cobalt, copper, lead, nickel, vanadium, and zinc). Metals were detected above background criteria as often in wells located at the AOC boundary on the northeast and southwest corners of EBG as in wells located in areas of known surface soil and sediment contamination. Maximum concentrations of SRCs ranged from 2 to 3 times background for those constituents whose background criteria were greater than zero.

Two SVOCs, bis(2-ethylhexyl)phthalate and di-n-butyl phthalate, were detected in one to two wells. The occurrence of SVOCs in groundwater was focused on wells located in the Track 49 embankment area and the T-Area. The VOC carbon disulfide was detected in seven of eight wells during the Phase II RI. The pesticide 4-4’-dichlorodiphenyltrichloroethene was detected in one well on the southwest corner of the AOC.

FATE AND TRANSPORT ANALYSIS

Contaminant fate and transport modeling performed as part of the Phase II RI included leachate modeling [Seasonal Soil Compartment (SESOIL)] of constituents in Track 49 embankment soil to the water table. Groundwater modeling [Analytical Transient 1-, 2-, 3-Dimensional (AT123D)] was conducted from the source to the nearest downgradient receptor (south surface water basin).

RDX and arsenic were identified as final contaminant migration contaminants of potential concern for EBG based on source loading predicted by the SESOIL modeling. These two constituents were also identified as final contaminant migration contaminants of concern based on AT123D modeling. The maximum groundwater concentrations of these constituents were predicted to exceed maximum contaminant levels (MCLs) or risk-based concentrations (RBCs) at the receptor within the model time frame of 1,000 years. RDX was not detected in samples collected from groundwater monitoring wells installed within the source area, indicating that factors such as attenuation and adsorption mitigate the leaching and migration of contaminants to a greater degree than assumed in the numerical model.

HUMAN HEALTH RISK ASSESSMENT

This human health risk assessment (HHRA) was conducted to evaluate risks and hazards and to calculate applicable RGOs associated with contaminated media at EBG at RVAAP for two representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker). Three media were evaluated: shallow surface soil (0 to 1 ft bgs), sediment, and surface water. In addition to the representative receptor described above, the other three receptors described in the *Facility-wide Human Health Risk Assessment Manual* [National Guard Trainee, Security Guard/Maintenance Worker, 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 FS (e.g., to establish the need for institutional controls). These additional receptors are not anticipated at EBG due to physical constraints (e.g., wetlands and munitions and explosives of concern) 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. Risks and hazards were evaluated and RGOs calculated for the Hunter/Trapper and Fire/Dust Suppression Worker and all other receptor scenarios. Results are discussed below for the representative receptors for each medium.

No surface soil or sediment chemicals of concern (COCs) were identified for either receptor at EBG. One metal (arsenic) was identified as a carcinogenic COC for the Fire/Dust Suppression Worker exposed to surface water at EBG.

Risk-based RGOs were computed for arsenic at a target risk (TR) of 10^{-5} and a target hazard index (THI) of 1; however, the exposure point concentration (EPC) used in this HHRA for arsenic was smaller than the most conservative risk-based RGO for the representative receptors.

Wildfowl concentrations were modeled for all chemicals of potential concern identified in the sediment and surface water at EBG. Subsequent calculations of risks and hazards resulted in the determination of four COCs for the Hunter/Trapper exposed via the ingestion of wildfowl pathway. Antimony and zinc were identified as non-carcinogenic COCs. Arsenic and benzo(*b*)fluoranthene were identified as carcinogenic COCs. Because the ingestion of wildfowl is not a direct contact pathway, risk-based RGOs were not computed for the four COCs.

The representative receptors are not exposed to groundwater. COCs identified for direct contact pathways for all media for the other receptors evaluated are listed below.

- Two COCs [arsenic and benzo(*a*)pyrene] were identified in shallow (0 to 1 ft bgs) surface soil.
- Three COCs (arsenic, chromium, and manganese) were identified in deep (0 to 3 ft bgs) surface soil.
- Two COCs [arsenic and benzo(*a*)pyrene] were identified in subsurface soil.
- One COC (arsenic) was identified in groundwater.
- Five COCs [antimony, arsenic, chromium, manganese, and benzo(*b*)fluoranthene] were identified in sediment.
- Two COCs (arsenic and manganese) were identified in surface water.

RGOs were calculated for all COCs identified for all receptors.

SCREENING ECOLOGICAL RISK EVALUATION

EBG 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 ecological risk assessment (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 Ecological Risk Work Plan (USACE 2003a) has been used to guide the work.

A Level II SERA and Level III baseline ecological risk assessment (BERA) were performed for EBG soils (surface and subsurface), sediment, and surface water using Ohio EPA and Army guidance methods. The Level II Screen consisted of a media-specific data evaluation and media evaluation of detected chemicals of intent, as well as a media screen. Chemicals whose concentrations exceeded or lacked the ecological screening values or Ohio Administrative Code water quality standards, as well as chemicals that were persistent, bioaccumulative, and toxic compounds, were retained as chemicals of potential ecological concern (COPECs).

Level II Results

Forty-five chemicals were retained as COPECs for surface soil. For subsurface soil (1 to 3 ft depth), 18 chemicals were retained as COPECs. Forty chemicals were retained as COPECs for sediment. Seventeen chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for surface and subsurface 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 were used to prepare a Level III Baseline.

Level III Results

Forty-three chemicals of ecological concern (COECs) for surface soil were identified for the surface soil exposure unit (EU). Three surface soil COPECs from the Level II SERA were identified as qualifying for no further action (NFA) during the Level III BERA. Fifteen COECs for the subsurface soil EU were identified. Four subsurface soil COPECs from the Level II SERA were identified as qualifying for NFA during the Level III BERA. Fifty-eight COECs were identified for the sediment EU. Only one sediment COPEC from the Level II SERA qualified for NFA during the Level III BERA. Nineteen COECs were identified for the surface water EU. None of the surface water COPECs from the Level II SERA qualified for NFA during the Level III BERA. The most likely outcomes, in order of likelihood, associated with the Scientific Management Decision Point (SMDP) for the ecological risk assessment (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 may 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 IV. In the FS, a WOE approach to the COPECs involved at EBG would assist in defining the best outcome or decision. Thus, the information in this Level III ERA 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 Phase I and II 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 primary mechanisms for releases of contaminants from source areas include: past thermal treatment of waste munitions, explosives, and associated wastes; leaching of constituents from residual ash and debris into site soils; and erosion of contaminated soils and redeposition in surface water bodies. Arsenic and RDX in surface and subsurface soils exceed conservative criteria for soil leaching to groundwater and were predicted to reach the nearest receptor (south basin) at concentrations exceeding MCLs or RBCs. The Phase II RI results indicate the absence of explosives in groundwater. Some inorganic metals and a few SVOCs and VOCs were detected in groundwater. The revised CSM suggests that factors such as adsorption, degradation, and dilution effects from groundwater/surface water interactions largely control leaching and migration of contaminants from soil sources to the surface water basins. Based on Phase II RI geologic data, it is assumed that substantial interaction between surface water and shallow groundwater within EBG results in very high dilution factors in the water table interval. Phase II RI characterization of the surface water exit pathway further demonstrates that minimal contaminant concentrations are currently exiting EBG via this pathway.

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 and subsurface soil, groundwater, sediment, and surface water at EBG at a hazard index of 1 or risk level of 10^{-5}.

Surface Soil

Explosives, metals, SVOCs, and VOCs were detected above background in surface soil samples at EBG. Fate and transport modeling indicates that RDX and arsenic may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs. Explosive compounds and inorganics above background levels were detected in the westernmost samples collected along the Track 49 embankment.

No surface soil human health COCs were identified for any exposure scenario or pathway for either of the representative receptors at EBG (Hunter/Trapper or Fire/Dust Suppression Worker). Two COCs [arsenic and benzo(*a*)pyrene] were identified in shallow (0 to 1 ft bgs) surface soil and three COCs (arsenic, chromium, and manganese) were identified in deep (0 to 3 ft bgs) surface soil for the other receptors evaluated.

The Level III BERA identified 43 COECs for surface soil at EBG.

Subsurface Soil

The Phase I RI indicated that explosives, metals, SVOCs, and VOCs occur in subsurface soil at concentrations exceeding background. Fate and transport modeling indicates that RDX and arsenic may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs.

Subsurface soil was not evaluated for the representative receptors at EBG. Two COCs [arsenic and benzo(*a*)pyrene] were identified in subsurface soil for the other receptors evaluated.

The Level III BERA identified 15 COECs for subsurface soil (1 to 3 ft depth) at EBG.

Sediment

Sediment SRCs include explosives, metals, SVOCs (phenol/phthalates and PAHs), VOCs, and a single occurrence of PCB-1254. Sampling results indicate the presence of low levels of only nitrobenzene, inorganic SRCs, and bis(2-ethylhexyl)phthalate at the inlet culverts, which suggest minimal influx of contaminants from upstream areas. The extent of explosives constituents in sediment downstream of the exit culvert was defined during the Phase II RI; however, some inorganics and PAHs were detected above background levels at the furthest downstream samples from the exit culvert.

No sediment COCs were identified for any exposure scenario or pathway for either the Hunter/Trapper or Fire/Dust Suppression Worker. Five COCs [antimony, arsenic, chromium, manganese, and benzo(*b*)fluoranthene] were identified in sediment for the other receptors evaluated.

The Level III BERA identified 58 COECs for sediment at EBG.

Surface Water

Explosives, propellants, metals, SVOCs, and VOCs were detected above background criteria in surface water samples at EBG. Surface water sampling results also indicate minimal influx of contaminants from upstream areas through the EBG inlet points, with only low concentrations of nitrocellulose at the east inlet and low concentrations of inorganic SRCs. Sampling of the stream downstream of the exit culvert indicated that no explosives, SVOCs, VOCs, pesticides, PCBs were not exiting the AOC under normal precipitation conditions.

One metal (arsenic) was identified as a carcinogenic COC for the Fire/Dust Suppression Worker exposed to surface water at EBG. No COCs were identified for the Hunter/Trapper. Risk-based RGOs were computed for arsenic at a TR of 10^{-5} and a THI of 1; however, the EPC used in this HHRA for arsenic was smaller than the most conservative risk-based RGO. Two COCs (arsenic and manganese) were identified in surface water for the other receptors evaluated.

Nineteen COECs were identified for surface water in the Level III BERA.

Groundwater

Sampling of groundwater within source areas at EBG indicates minimal impacts related to AOC operations. Explosives were not detected in any of the groundwater wells installed and sampled during the Phase II RI. Concentrations of inorganic SRCs were similar in wells located within the principal source areas (the T-Area and the Track 49 embankment) and the upgradient AOC boundary. Low levels of SVOCs, one VOC, and one pesticide were detected in one to two wells. Few SVOC, VOCs, and pesticides/PCBs were present at detectable concentrations.

The representative receptors at EBG are not exposed to groundwater. One COC (arsenic) was identified in groundwater for the other receptors evaluated.

LESSONS LEARNED

A key project quality objective for the Phase II RI at EBG 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 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.

- Provisions for better delineating multi-increment irregularly shaped sampling areas in rough and heavily vegetated terrain should be incorporated into future project scoping efforts. Use of a backpack global positioning system, along with selected surveyed reference points, may be used to help better delineate such sampling areas.

- Any potential future application of multi-increment sampling techniques to subaqueous or extremely wet sediments must account for the fact that such samples may contain a high clay/silt content and do readily air dry within a short timeframe. These characteristics make sieving and mixing of such samples difficult, which could potentially introduce some bias to the samples.

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 EBG 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 remedy in place for the AOC by focusing the FS efforts to appropriate remedies based on site conditions and land use considerations. EBG is an ideal candidate for a focused FS approach because of the limited extent of contamination and the presence of extensive wetland areas effectively precludes many land uses. For surface water and groundwater, the FS for EBG 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. It is noted that low levels of explosives were detected in soil samples collected furthest west along the Track 49 embankment; however, substantial data gaps have not been identified following completion of the Phase II RI.

The future land uses and controls envisioned for EBG 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 and attendant Land Use Controls Assurance Plan, 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.

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1.0 INTRODUCTION

This report documents the results of the Phase II remedial investigation (RI) at Erie Burning Grounds (EBG) at the U. S. Army Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio (Figures 1-1 and 1-2). The Phase II RI was conducted under the U. S. Department of Defense Installation Restoration Program (IRP) by Science Applications International Corporation (SAIC) and their subcontractors, under contract number GS-10F-0076J, Delivery Order No. W912QR-05-F-0033, with the U. S. Army Corps of Engineers (USACE), Louisville District. The Phase II 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 document summarizes the results of the Phase II RI field activities conducted in November and December 2003 at EBG. The field program, environmental setting, and nature and extent of contamination are discussed. Contaminant fate and transport modeling, a baseline human health risk assessment, and screening ecological risk assessment (SERA) are used to develop a conceptual site model (CSM) for EBG that summarizes the results of the investigation, presents conclusions, and forms the framework for decisions regarding future IRP actions at EBG.

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 outlined in the RVAAP Installation Action Plan and 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 (USACHPPM) and entered into the Army's 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 the Phase II RI is to determine the nature and extent of contamination so that quantitative human health and ecological risk assessments (ERAs) can be performed. Depending upon the outcome of the risk assessments, an AOC will either require no further action (NFA) or will be the subject of a feasibility study (FS) to evaluate potential remedies and future actions.

The scope of this investigation is to determine the extent of contamination in affected media (soils, sediments, surface water, and groundwater) identified during the Phase I RI at EBG. The primary project objectives for the Phase II RI of EBG are as follows:

- Assess the presence or absence and map the extent of AOC-related contaminants in the uppermost groundwater-producing zone in the immediate area.

- Conduct limited surface soil sampling of the western portion of the Track 49 embankment, the area south of the east leg of the T-Area, and the northwestern wooded area to complete the evaluation of contaminant nature and extent.

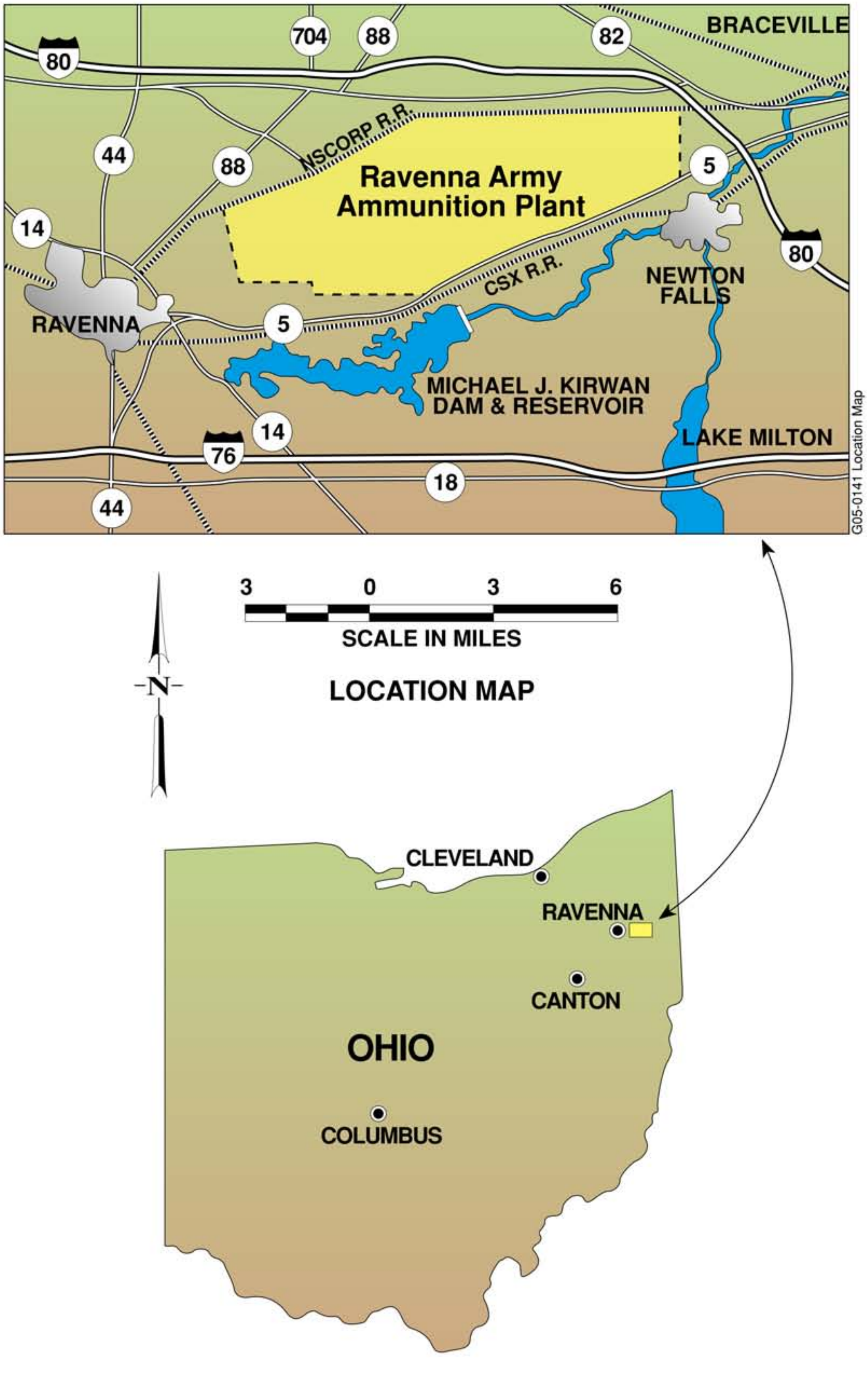
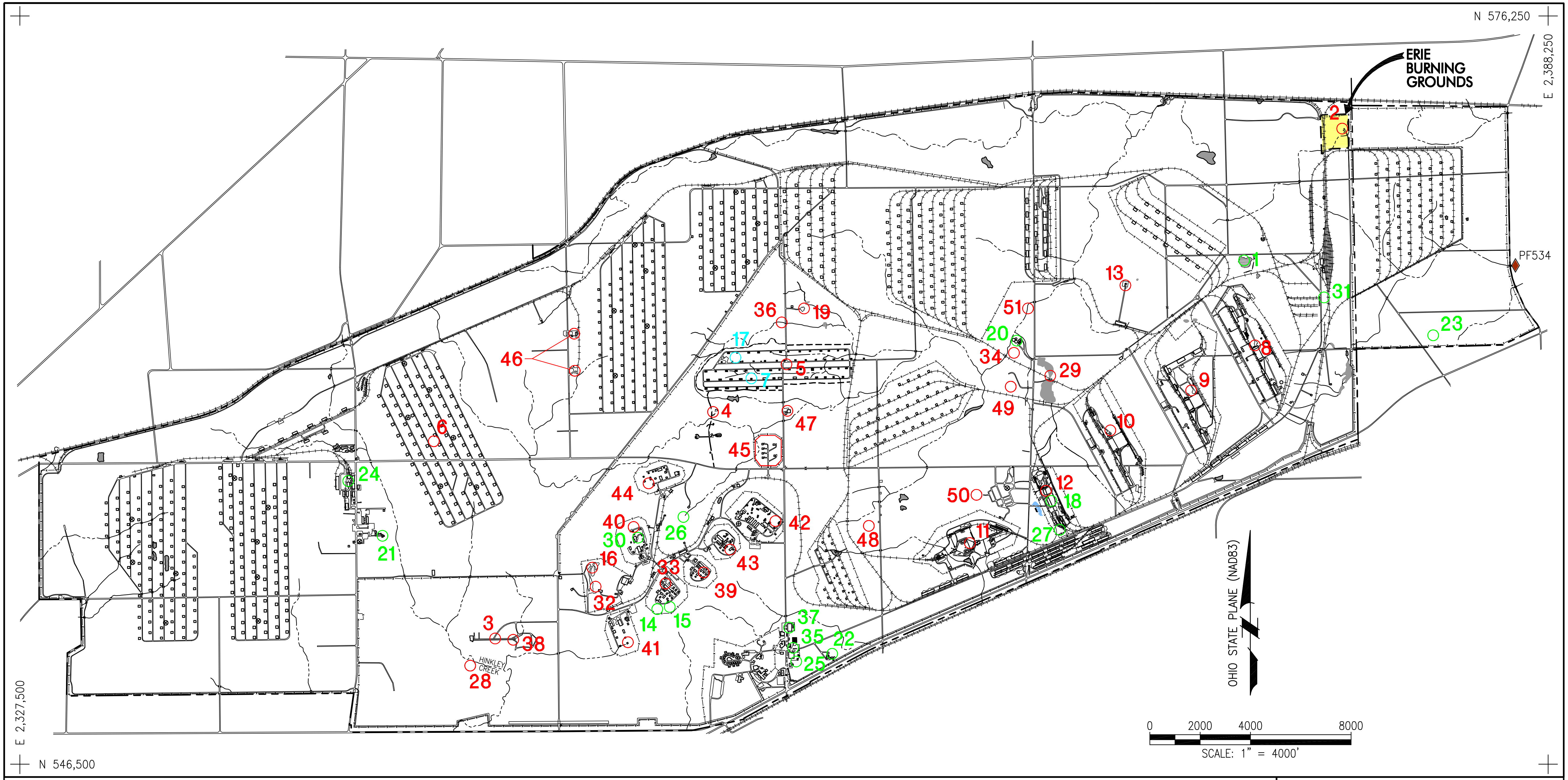


Figure 1-1. General Location and Orientation of RVAAP



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 WASTEWATER 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
◆	STATION PF534

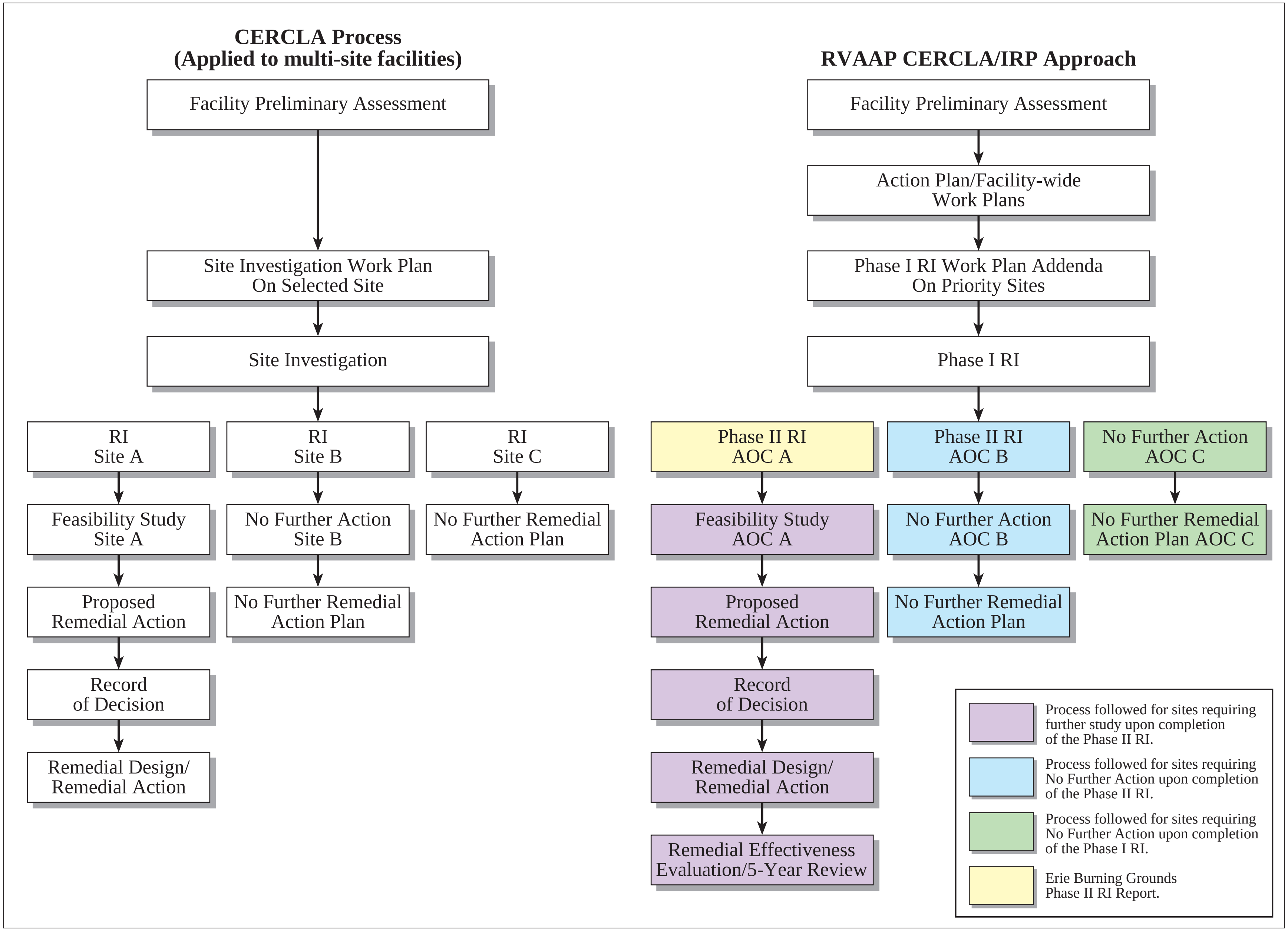
US Army Corps
of Engineers
Louisville District

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

RAVENNA ARMY
AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	1 / 08–23–04	/03025/DWGS/S80LOC01

Figure 1-2. Ravenna Army Ammunition Plant Facility Map



G03-0267 EBG

Figure 1-3. CERCLA Approach at RVAAP

- Conduct sediment and surface water sampling at selected locations to delineate the extent of contaminants downstream of EBG, identify if any contaminant flux is occurring from upstream sources, and evaluate temporal trends in contaminated media identified during the Phase I RI.

- Conduct human health and ecological risk evaluations and develop human health risk-based remedial goal options (RGOs) for use in determining areas that may require remediation in evaluating remedial alternatives in a subsequent FS.

- Update AOC site characteristics and refine the CSM based on groundwater information collected during the Phase II RI.

- Assess any remaining data gaps with respect to sources and extent of soil, sediment, and surface water contamination identified during the Phase I and Phase II RIs and provide recommendations for a path forward for the AOC.

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 2001a). The DQOs specific to the EBG Phase II RI are discussed in Section 1.3.4.

The investigation approach to the Phase II RI at EBG involved a combination of field and laboratory activities to characterize the AOC. Field investigation techniques included soil boring and sampling, as well as sampling of surface water, sediment, and groundwater. 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 II Remedial Investigation of Erie Burning Grounds at the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2003a).

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 Base Reallignment and Closure 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

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. Census figures for 2000 indicate that the 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 closest major recreational area, the Michael J. Kirwan Reservoir (also known as West Branch Reservoir), 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 the Ohio Army National Guard (OHARNG). Training and related activities, managed under the Ravenna Training and Logistics Site (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 to NGB, effective May 1999, for expanded training missions. On May 13, 2002, an additional 3,774 acres of land was transferred 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 (OHARNG 2001), which address 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 ERIE BURNING GROUNDS SITE DESCRIPTION

A detailed history of process operations and waste processes for the original 38 identified AOCs at RVAAP, including EBG, 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 EBG.

1.3.1 Operational History

EBG, designated as AOC RVAAP-02, was in operation from 1941 to 1951 and covers approximately 14.2 ha (35 acres). The burning grounds are situated on the northeastern corner of the facility (see Figure 1-2). Figure 1-5 depicts the cultural landmarks and other reference points within EBG that will be mentioned throughout this report. The site was used to conduct open burning of explosives and related materials. Prior to its acquisition by the Army in 1940, the area may have been used for brick manufacturing (Jacobs Engineering 1989). Bulk, obsolete, non-specification explosives, as well as propellants, rags, and Army railcars used for transporting explosives, were treated at EBG.

Aerial photos of the site from the 1940s and 1950s depict open boxcars staged at the end of the rail spur, known as Track 49. Presumably, materials were either tipped out of the cars on either side of the embankment to be burned. Evidence of activity in the aerial photos is indicated at the northeastern terminus of the rail spur, where it meets the gravel approach road. Engineering drawings dated 1941 show a waste chute on the north side of Track 49 approximately 200 ft from the terminus; the chute leads to a designated burning area on the drawings. Three pairs of trenches, now approximately 4 ft deep, were dug at EBG, perhaps to collect water and to serve as containment barriers for fires set within the "T-Area" between the trenches. These ditches were connected to the original creek channel that flowed through the approximate center of the site, about 300 ft west of the T-Area. A borrow area between Tracks 10 and 49 may potentially have been used for disposal by open burning. Unspecified large metal items were also treated to remove explosive residues. Metal items were salvaged and processed as scrap (Jacobs Engineering 1989). Ash residues from open burning remained on the site.

The principal sources of contaminants are the ash residues derived from the burning of 2,4,6-TNT; hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); and propellants. These residues potentially contain small amounts of explosives and heavy metals. Estimates of the quantities of wastes disposed by burning at EBG have reached as high as one million pounds (Jacobs Engineering 1989), but it is unknown if this figure is accurate.

Current conditions at EBG differ greatly from those during its active life. The area became a wetland in the early 1990s as a consequence of sedimentation and vegetation growth and beaver damming of the small stream that drains the burning ground. Four main surface water basins now occupy the lowlands at the site. The largest surface water basin north of Track 49 (see Figure 1-5) has periodically drained on its own. The current depth of the water in the pond reaches a maximum of 5 ft within the former drainage

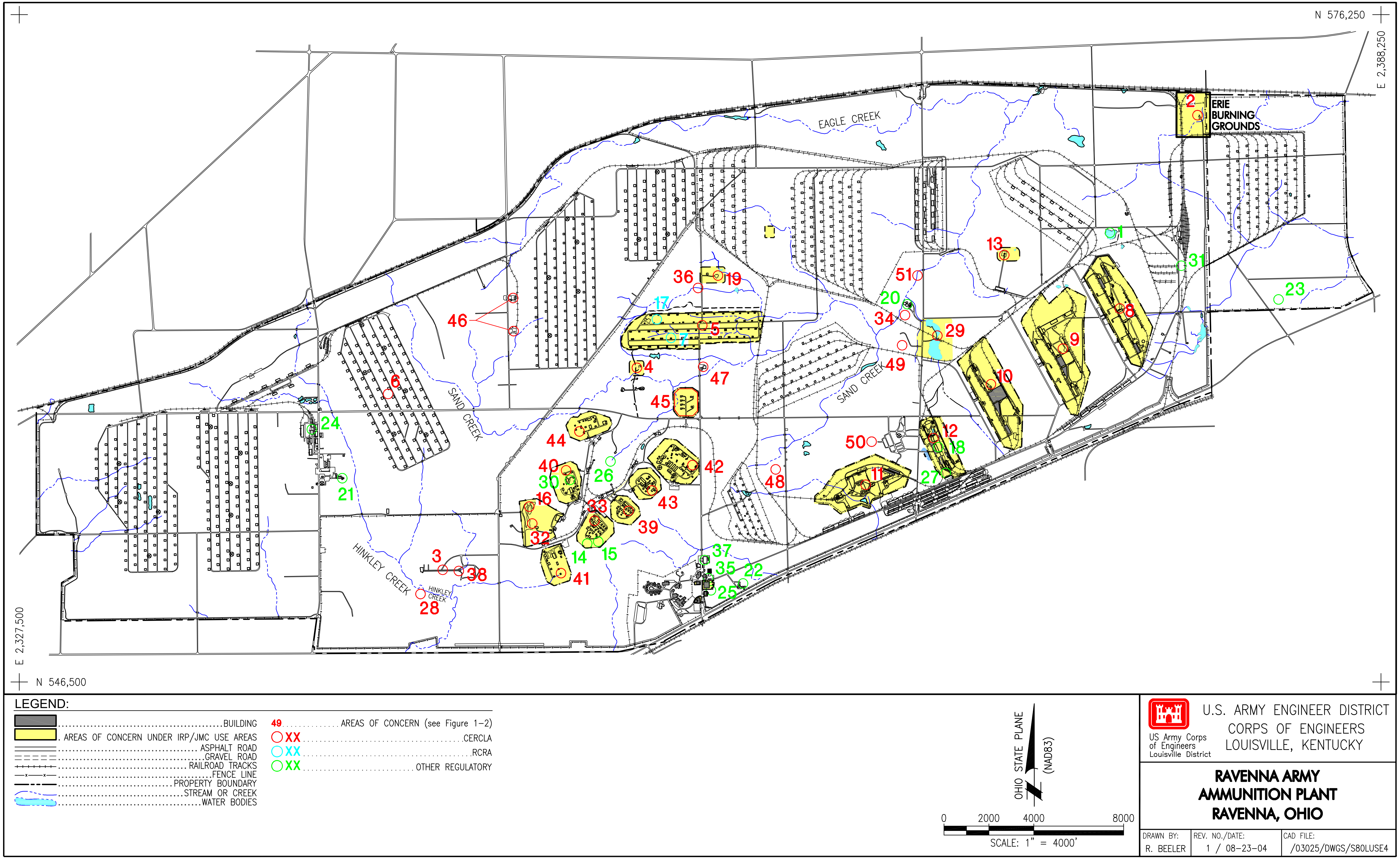


Figure 1-4. Current Land Use at RVAAP

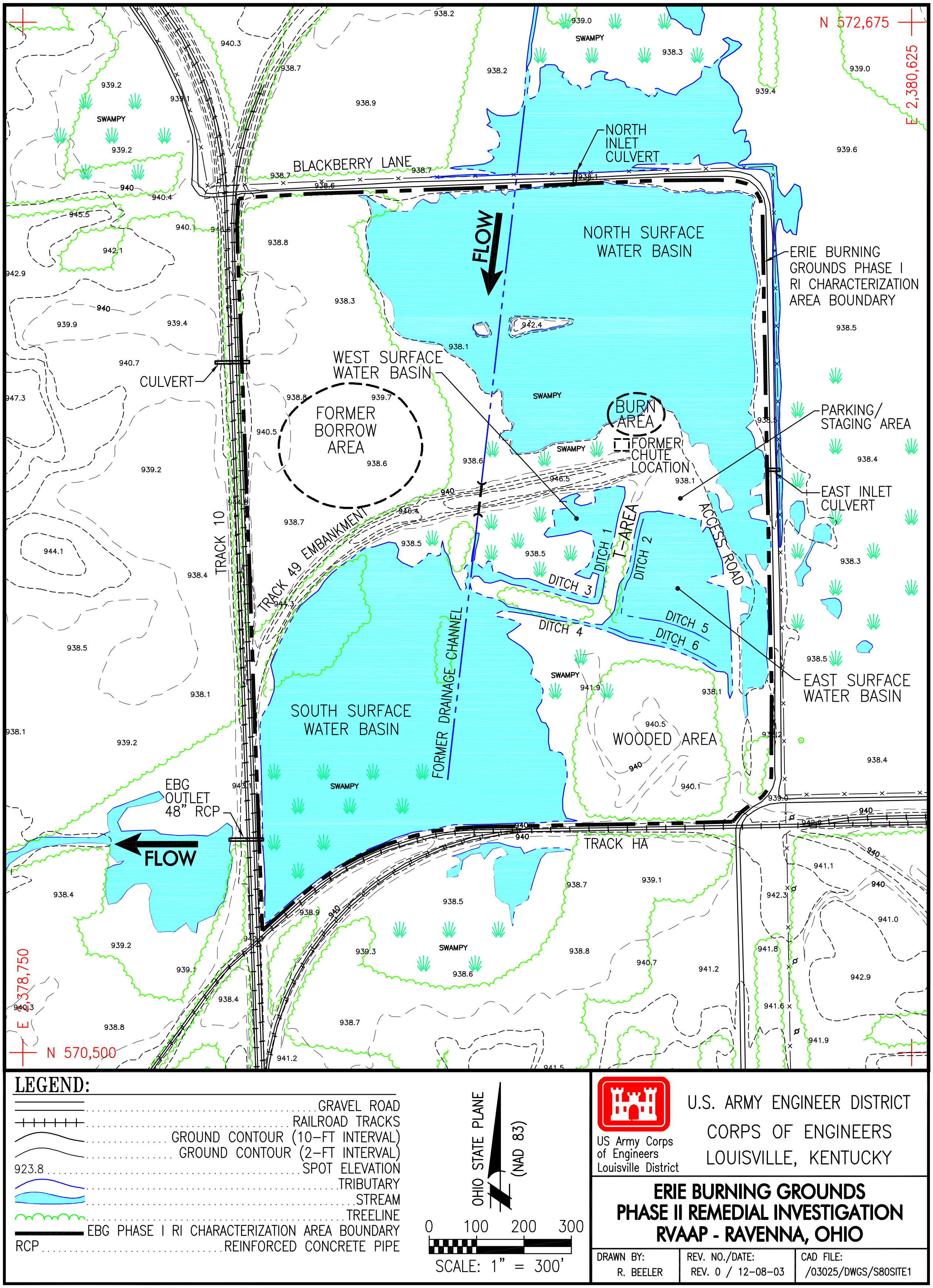


Figure 1-5. Erie Burning Grounds Site Map

channel, but is generally less than 1 ft in most areas. Wetlands extend to the north and east beyond EBG. Surface water within EBG is connected to these adjacent wetlands by two culverts beneath Blackberry Lane along the east and north border of the site. Surface water flow is from the north into EBG with drainage from the site to the southwest through a 48-in. diameter, reinforced concrete pipe beneath Track 10. A second exit culvert in the northwest portion of the AOC flows only during periods of very high rainfall.

The areas that remain above water (Figure 1-5) include: (1) the railroad embankment and track, (2) the gravel access road, (3) a portion of the elevated T-Area between the two pairs of parallel trenches, (4) the portion of the site northwest of the soil borrow area, and (5) a wooded area adjacent to the T-Area near the southeast corner of EBG. Dense brush vegetation now covers the portions of the site that are not submerged.

1.3.2 Previous Investigations at Erie Burning Grounds

Table 1-1 presents a summary of the results from previous investigations performed at EBG. Four previous investigations have been conducted: (1) Soil and Sediment Analyses, RVAAP (Mogul Corporation 1982); (2) Water Quality Surveillance Program (USATHAMA 1980-1992); (3) RRSE (USACHPPM 1996); and (4) the Phase I RI for EBG (USACE 2001c).

The 1982 investigation by Mogul Corporation included soil sampling at five locations within EBG, followed by analyses for the explosives TNT and RDX. Samples from EBG had non-detectable quantities of these analytes.

The Water Quality Surveillance Program was conducted at nine sampling locations throughout RVAAP. Of the sample locations, the one of interest to this study was a Parshall flume located near the eastern boundary of the installation, adjacent to Route 534 (station PF534). All surface water drainage that exits EBG discharges off the installation through this sampling point. However, the station includes drainage from a large area in addition to EBG. Copper, chromium, hexavalent chromium, lead, zinc, TNT, and RDX were monitored annually in surface water. Cadmium was added to the annual list of metal analytes between 1988 and 1992. Indicator parameters such as pH, temperature, specific conductance, dissolved oxygen, oil and grease, total suspended solids, fecal coliform, and biochemical oxygen demand were monitored quarterly. Total organic carbon (TOC), total Kjehldal nitrogen, nitrate, nitrite, and phosphorus were evaluated semi-annually. Samples collected and analyzed from station PF534 between 1980 and 1992 had no detectable quantities of explosives, with the exception of a November 5, 1987, sample (RDX at 64 µg/L) that was subsequently re-analyzed with a result of < 0.25 µg/L. Low concentrations of zinc and copper were occasionally detected. Hexavalent chromium was detected on one occasion in 1985.

The RRSE performed for EBG was limited to the evaluation of surface water and sediment. Two samples each of surface water and sediment were analyzed for explosives and metals. For surface water, only lead exceeded the RRSE standard criteria, and the contaminant hazard factor was determined to be “moderate.” However, a potential migration pathway was identified and a potential receptor point (recreational users with no site controls) was identified. On this basis, the surface water/human endpoint was assessed as a “high” relative risk. For sediment, concentrations of arsenic, barium, chromium, copper, and zinc were detectable, but maximum levels were below the RRSE standard criteria. Accordingly, the contaminant hazard factor was determined to be “minimal.” However, a migration pathway (surface water) and potential receptor (recreational user) were identified. Thus, the sediment/human endpoint was assessed as a “moderate” relative risk.

Table 1-1. Summary of Historical Analytical Data for EBG[a]

Parameter	Minimum	Maximum	Mean[b]	No. of Detects per No. of Results
Sampling Program: PF534 Surveillance (water, μg/L)[c]				
RDX	64[d]	64[d]	64[d]	1/9[d]
Chromium, hexavalent	11	11	11	1/9
Copper	10	25	17.5	2/9
Zinc	20	99	43.5	4/9
Sampling Program: RRSE (surface water, μg/L)[e]				
Arsenic	4	4	4	1/2
Barium	27	29	28	2/2
Copper	29	29	29	1/2
Lead	11	16	135	2/2
Sampling Program: RRSE (sediment, mg/kg)[e]				
Arsenic	3.99	9.94	6.96	2/2
Barium	35.7	113	74.4	2/2
Chromium	3.61	18.6	11.1	2/2
Copper	5.31	32.8	19.06	2/2
Zinc	38.3	217	127.65	2/2

[a] Sample summary shows detections of potential contaminants of concern at EBG only.
[b] Mean value includes only detected values.
[c] *Source:* USATHAMA (1980–1992).
[d] Subsequent re-analysis of the sample showed no detectable RDX.
[e] *Source:* USACHPPM 1996.
EBG = Erie Burning Grounds.
PR = Parshall flume.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RRSE = Relative Risk Site Evaluation.

The Phase I RI results indicate levels of explosive, organic, and inorganic constituents above human health and ecological risk evaluation screening levels in soil, sediment, and surface water. A total of 59 surface soil samples, 42 subsurface soil samples, 86 sediment samples, and 18 surface water samples were collected and analyzed for the Phase I RI (see Figures 1-6 and 1-7). The Phase I RI did not include an assessment of the AOC groundwater. Full results are contained in the Final Phase I RI Report (USACE 2001c). Based on the human health and ecological screening risk evaluations, contaminants of potential concern were identified for soil, sediment, and surface water within EBG. Based on the current and near future use and site conditions, the likelihood of exposure of human receptors to contaminants within EBG is low. However, a majority of the site is wetland, and site observations indicate that terrestrial and aquatic ecological receptors are present. Therefore, current site conditions do not support a "NFA" decision. Additional characterization and a baseline human health and ERA were recommended under the auspices of a Phase II RI.

1.3.3 Chemicals of Potential Concern

Based on available process knowledge and previous investigation results, the primary sources of contamination at EBG are explosives residues [e.g., 2,4,6-TNT; RDX; and dinitrotoluene (DNT)] from the open burning of explosives and thermal treatment of munitions and associated metals (e.g., cadmium, chromium, lead, mercury, copper, zinc). The Phase I RI included identification of site-related contaminants (SRCs) for soil, sediment, and surface water (Tables 1-2 through 1-5). These

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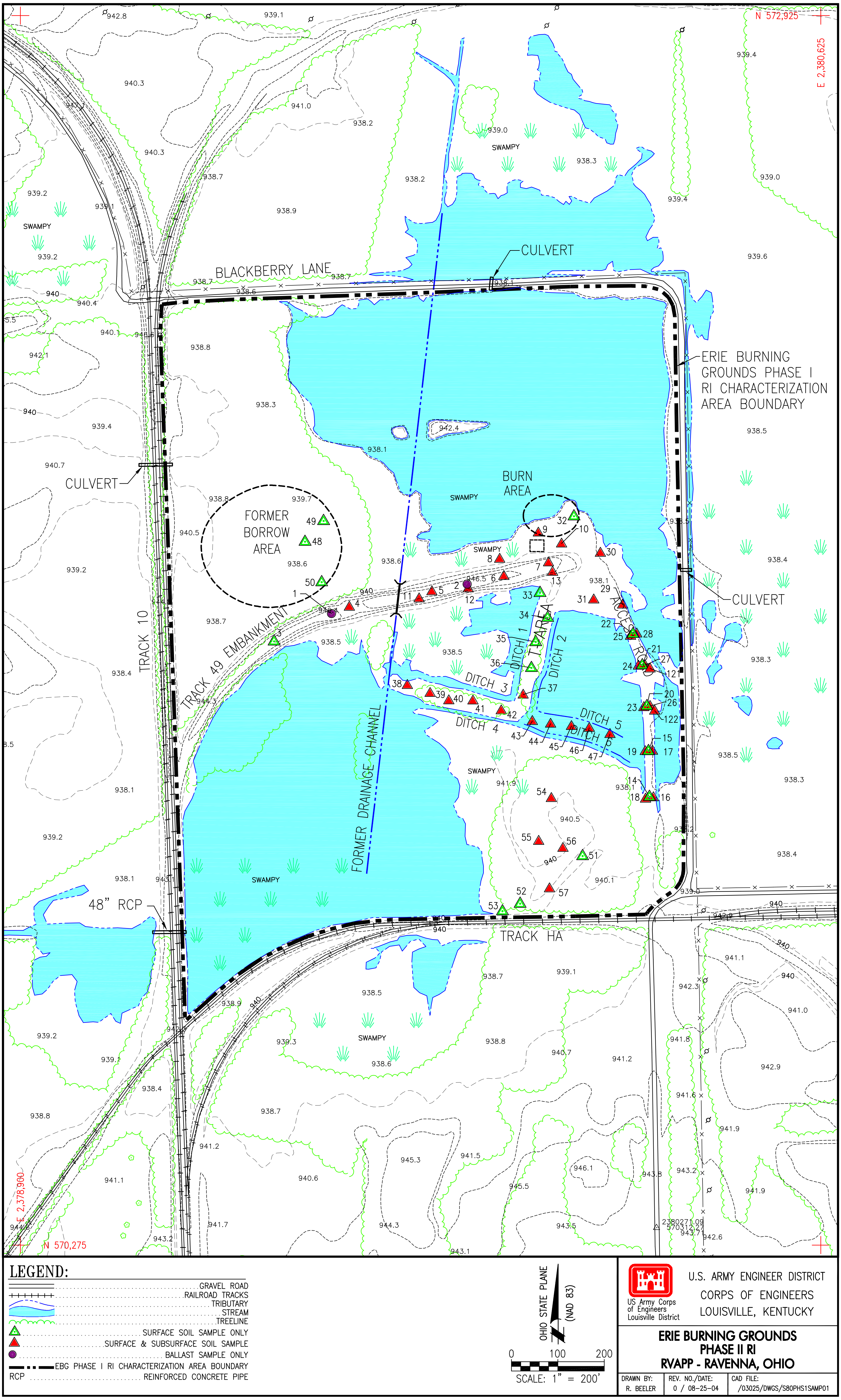
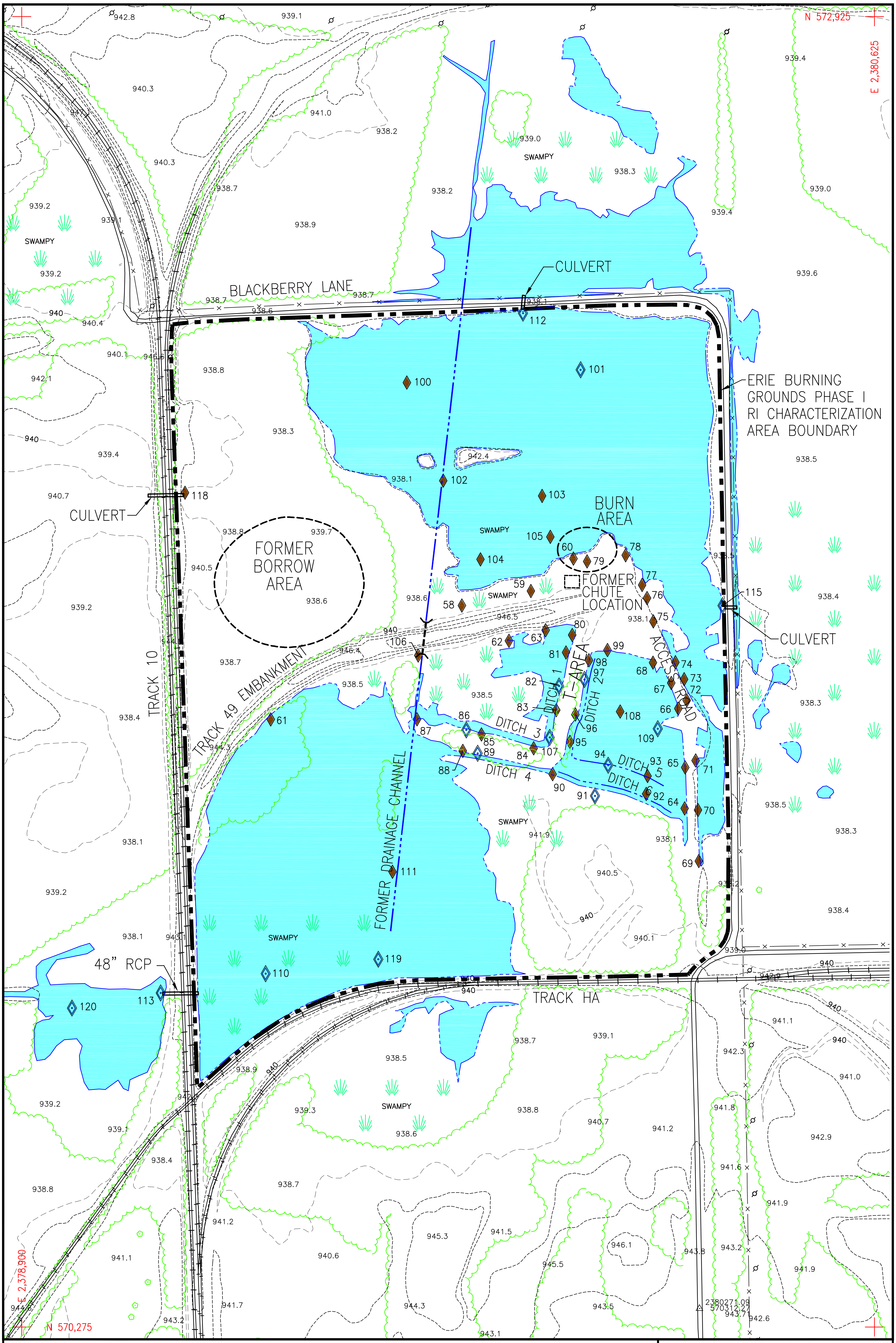


Figure 1-6. Surface Soil/Subsurface Soil Sampling Locations, EBG Phase I RI



LEGEND:

- ════ ……………… GRAVEL ROAD
- ┼┼┼┼ ……………… RAILROAD TRACKS
- ……………… TRIBUTARY
- ……………… STREAM
- ……………… TREELINE
- ◇ ……………… SEDIMENT/SURFACE WATER SAMPLING LOCATION
- ◆ ……………… SEDIMENT SAMPLING LOCATION
- ─·─·─ ……………… EBG PHASE I RI CHARACTERIZATION AREA BOUNDARY
- RCP ……………… REINFORCED CONCRETE PIPE

NOTE:

1.) LOCATIONS EBG-116, EBG-117, AND EBG-114 (AT PFS34) NOT SHOWN. COLLECTED DOWNSTREAM OF EBG.

OHIO STATE PLANE (NAD 83)

0 100 200

SCALE: 1" = 200'

US Army Corps of Engineers Louisville District

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

ERIE BURNING GROUNDS
PHASE II RI
RVAAP - RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	0 / 08-27-04	/03025/DWGS/S80PHS1SAMP02

Figure 1-7. Surface Water/Sediment Sampling Locations, EBG Phase I RI

Table 1-2. Site-related Contaminants in Surface Soil, EBG Phase I RI

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Explosives and Propellants							
1,3,5-Trinitrobenzene	mg/kg	2/57	0.14	0.10	0.91	0	Yes
2,4,6-Trinitrotoluene	mg/kg	12/57	0.31	0.05	7.10	0	Yes
2,4-Dinitrotoluene	mg/kg	1/57	0.13	0.62	0.62	0	Yes
4-Nitrotoluene	mg/kg	4/57	0.13	0.10	0.20	0	Yes
Nitrocellulose as N	mg/kg	4/48	1.49	2.60	5.90	0	Yes
Inorganics							
Aluminum	mg/kg	59/59	11510.00	875.00	30200.00	17700.00	Yes
Antimony	mg/kg	23/59	5.90	2.50	91.70	0.96	Yes
Arsenic	mg/kg	59/59	8.85	2.60	24.10	15.40	Yes
Barium	mg/kg	59/59	126.30	16.60	1050.00	88.40	Yes
Beryllium	mg/kg	16/59	0.66	0.25	3.80	0.88	Yes
Cadmium	mg/kg	9/59	1.06	0.76	19.80	0.00	Yes
Calcium[b]	mg/kg	58/59	18060.00	202.00	122000.00	15800.00	No
Chromium	mg/kg	59/59	15.79	3.40	87.90	17.40	Yes
Cobalt	mg/kg	58/59	5.87	1.40	17.30	10.40	Yes
Copper	mg/kg	59/59	10	5.70	586.00	17.70	Yes
Cyanide	mg/kg	12/59	0.98	0.41	32.50	0.00	Yes
Iron[b]	mg/kg	59/59	17020.00	4500.00	63700.00	23100.00	No
Lead	mg/kg	59/59	80.86	8.90	1060.00	26.10	Yes
Magnesium[b]	mg/kg	59/59	3608.00	162.00	17000.00	3030.00	No
Manganese	mg/kg	59/59	684.00	13.40	3820.00	1450.00	Yes
Mercury	mg/kg	17/59	0.04	0.01	0.14	0.04	Yes
Nickel	mg/kg	59/59	18.88	2.20	90.50	21.10	Yes
Potassium[b]	mg/kg	56/59	889.30	236.00	2250.00	927.00	No
Selenium	mg/kg	1/59	0.45	3.50	3.50	1.40	No
Silver	mg/kg	3/59	0.68	0.88	3.10	0.00	Yes
Sodium[b]	mg/kg	33/38	252.60	33.20	774.00	123.00	No
Thallium	mg/kg	10/17	0.29	0.17	0.50	0.00	Yes
Vanadium	mg/kg	59/59	21	3.50	112.00	31.10	Yes
Zinc	mg/kg	54/59	312.30	29.40	5340.00	61.80	Yes
Semivolatile Organic Constituents							
2-Methylnaphthalene	mg/kg	2/56	0.25	0.04	0.05	0	No
Acenaphthylene	mg/kg	1/56	0.25	0.23	0.23	0	No
Anthracene	mg/kg	3/56	0.25	0.04	0.46	0	Yes
Benzo(*a*)anthracene	mg/kg	9/56	0.26	0.06	1.70	0	Yes
Benzo(*a*)pyrene	mg/kg	9/56	0.27	0.05	1.80	0	Yes
Benzo(*b*)fluoranthene	mg/kg	12/56	0.31	0.05	3.90	0	Yes
Benzo(*g,h,i*)perylene	mg/kg	5/56	0.26	0.06	0.95	0	Yes
Benzo(*k*)fluoranthene	mg/kg	7/56	0.26	0.05	1.50	0	Yes
Bis(2-ethylhexyl)phthalate	mg/kg	22/56	0.35	0.04	3.50	0	Yes
Carbazole	mg/kg	3/56	0.24	0.05	0.16	0	Yes
Chrysene	mg/kg	10/56	0.28	0.06	2.40	0	Yes
Dibenzo(*a,h*)anthracene	mg/kg	1/56	0.25	0.32	0.32	0	No
Fluoranthene	mg/kg	13/56	0.27	0.05	1.90	0	Yes
Indeno(1,2,3-*cd*)pyrene	mg/kg	6/56	0.26	0.05	1.10	0	Yes
Phenanthrene	mg/kg	7/56	0.24	0.04	0.45	0	Yes
Pyrene	mg/kg	12/56	0.26	0.04	1.90	0	Yes
Volatile Organic Constituents							
Acetone	mg/kg	1/ 5	0.01	0.01	0.01	0	Yes
Methylene Chloride	mg/kg	1/ 5	0.00266	0.00059	0.00059	0	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.

RI = Remedial investigation.

Table 1-3. Site-related Contaminants in Subsurface Soil, EBG Phase I RI

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Explosives and Propellants							
2,4,6-Trinitrotoluene	mg/kg	3/41	0.20	0.10	3.20	0	Yes
2,4-Dinitrotoluene	mg/kg	1/41	0.12	0.09	0.09	0	Yes
3-Nitrotoluene	mg/kg	1/41	0.13	0.22	0.22	0	Yes
4-Nitrotoluene	mg/kg	2/41	0.12	0.11	0.12	0	Yes
HMX	mg/kg	1/41	0.25	0.20	0.20	0	Yes
Nitrocellulose as N	mg/kg	1/14	1.47	2.90	2.90	0	Yes
Inorganics							
Aluminum	mg/kg	42/42	10690.00	1410.00	18300.00	19500.00	No
Antimony	mg/kg	4/42	2.84	3.00	7.00	0.96	Yes
Arsenic	mg/kg	42/42	8.12	1.10	19.40	19.80	No
Barium	mg/kg	42/42	111.70	12.30	263.00	124.00	Yes
Beryllium	mg/kg	5/42	0.38	0.57	1.40	0.88	Yes
Cadmium	mg/kg	5/42	0.48	0.18	1.80	0.00	Yes
Calcium[a]	mg/kg	42/42	4948.00	148.00	20000.00	35500.00	No
Chromium	mg/kg	42/42	14.81	4.50	26.00	27.20	No
Cobalt	mg/kg	42/42	6.14	1.60	14.90	23.20	No
Copper	mg/kg	42/42	25.72	5.20	90.50	32.30	Yes
Cyanide	mg/kg	1/42	0.34	0.65	0.65	0.00	No
Iron[a]	mg/kg	42/42	14050.00	5380.00	26100.00	35200.00	No
Lead	mg/kg	42/42	24.38	7.20	129.00	19.10	Yes
Magnesium[a]	mg/kg	42/42	2180.00	333.00	3950.00	8790.00	No
Manganese	mg/kg	42/42	252.00	28.20	1230.00	3030.00	No
Mercury	mg/kg	11/42	0.04	0.02	0.10	0.04	Yes
Nickel	mg/kg	42/42	17.83	5.40	35.90	60.70	No
Potassium[a]	mg/kg	40/42	770.00	245.00	1370.00	3350.00	No
Selenium	mg/kg	2/42	0.51	2.30	3.20	1.50	No
Sodium[a]	mg/kg	19/25	110.30	35.80	365.00	145.00	No
Thallium	mg/kg	10/15	0.38	0.20	0.88	0.91	No
Vanadium	mg/kg	42/42	18.84	5.90	36.00	37.60	No
Zinc	mg/kg	38/38	97.74	30.70	622.00	93.30	Yes
Semivolatile Organic Constituents							
Benzo(*a*)anthracene	mg/kg	2/42	0.21	0.05	0.06	0	No
Benzo(*a*)pyrene	mg/kg	3/42	0.21	0.07	0.07	0	Yes
Benzo(*b*)fluoranthene	mg/kg	3/42	0.21	0.08	0.15	0	Yes
Benzo(*k*)fluoranthene	mg/kg	3/42	0.21	0.05	0.07	0	Yes
Bis(2-ethylhexyl)phthalate	mg/kg	19/42	0.24	0.05	1.20	0	Yes
Chrysene	mg/kg	3/42	0.21	0.06	0.10	0	Yes
Fluoranthene	mg/kg	3/42	0.21	0.06	0.25	0	Yes
Indeno(1,2,3-*cd*)pyrene	mg/kg	1/42	0.22	0.05	0.05	0	No
Phenanthrene	mg/kg	1/42	0.22	0.28	0.28	0	No
Phenol	mg/kg	1/42	0.22	0.05	0.05	0	No
Pyrene	mg/kg	3/42	0.21	0.04	0.16	0	Yes
Volatile Organic Constituents							
Acetone	mg/kg	3/4	0.01	0.01	0.02	0	Yes
Methylene Chloride	mg/kg	1/7	0.00371	0.0038	0.0038	0	Yes
Toluene	mg/kg	1/7	0.01	0.03	0.03	0	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.
RI = Remedial investigation.

Table 1-4. Site-related Contaminants in Sediment, EBG Phase I RI

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Explosives and Propellants							
1,3,5-Trinitrobenzene	mg/kg	1/ 86	0.13	0.15	0.15	0	Yes
2,4,6-Trinitrotoluene	mg/kg	16/ 86	1.32	0.05	95.00	0	Yes
2,4-Dinitrotoluene	mg/kg	5/ 86	0.12	0.10	0.14	0	Yes
2,6-Dinitrotoluene	mg/kg	7/ 86	0.14	0.11	0.28	0	Yes
2-Nitrotoluene	mg/kg	1/ 86	0.13	0.23	0.23	0	Yes
3-Nitrotoluene	mg/kg	2/ 86	0.13	0.14	0.16	0	Yes
4-Nitrotoluene	mg/kg	5/ 86	0.13	0.12	0.22	0	Yes
HMX	mg/kg	1/ 86	0.27	1.10	1.10	0	Yes
Nitrobenzene	mg/kg	11/ 86	0.12	0.05	0.19	0	Yes
Nitrocellulose as N	mg/kg	7/ 25	4.51	5.30	19.70	0	Yes
Inorganics							
Aluminum	mg/kg	86/ 86	11960.00	214.00	34800.00	13900.00	Yes
Antimony	mg/kg	26/ 86	93.48	3.70	3160.00	0.00	Yes
Arsenic	mg/kg	86/ 86	12.04	1.30	119.00	19.50	Yes
Barium	mg/kg	86/ 86	256.50	28.90	2170.00	123.00	Yes
Beryllium	mg/kg	1/ 86	0.49	2.10	2.10	0.38	No
Cadmium	mg/kg	14/ 86	2.58	0.80	44.80	0.00	Yes
Calcium[b]	mg/kg	86/ 86	8956.00	942.00	82600.00	5510.00	No
Chromium	mg/kg	84/ 84	32.44	5.40	253.00	18.10	Yes
Cobalt	mg/kg	81/ 86	7.67	1.30	17.50	9.10	Yes
Copper	mg/kg	86/ 86	120.60	5.30	1140.00	27.60	Yes
Cyanide	mg/kg	6/ 86	0.87	0.39	8.30	0.00	Yes
Iron[b]	mg/kg	86/ 86	25470.00	1200.00	242000.00	28200.00	No
Lead	mg/kg	86/ 86	187.70	7.10	1870.00	27.40	Yes
Magnesium[b]	mg/kg	86/ 86	2427.00	588.00	10300.00	2760.00	No
Manganese	mg/kg	86/ 86	433.90	21.80	7390.00	1950.00	Yes
Mercury	mg/kg	20/ 86	0.10	0.05	0.34	0.06	Yes
Nickel	mg/kg	85/ 86	30.20	4.50	177.00	17.70	Yes
Potassium[b]	mg/kg	86/ 86	891.40	128.00	2180.00	1950.00	No
Silver	mg/kg	16/ 86	1.69	0.68	6.20	0.00	Yes
Sodium[b]	mg/kg	29/ 40	438.60	97.40	2460.00	112.00	No
Thallium	mg/kg	1/ 14	0.35	0.72	0.72	0.89	No
Vanadium	mg/kg	85/ 86	20.81	6.70	51.00	26.10	Yes
Zinc	mg/kg	84/ 84	1095.00	13.90	18400.00	532.00	Yes
Miscellaneous							
Total Organic Carbon	mg/kg	10/ 10	20910.00	4100.00	35000.00	0	NA
PCBs							
PCB-1254	mg/kg	1/ 17	0.04	0.11	0.11	0	Yes
Semivolatile Organic Constituents							
4-Methylphenol	mg/kg	5/ 86	0.56	0.06	0.15	0	Yes
Benzo(*a*)anthracene	mg/kg	9/ 86	0.54	0.05	0.27	0	Yes
Benzo(*a*)pyrene	mg/kg	3/ 86	0.56	0.11	0.37	0	No
Benzo(*b*)fluoranthene	mg/kg	9/ 86	0.55	0.08	0.70	0	Yes
Benzo(*g,h,i*)perylene	mg/kg	1/ 86	0.57	0.08	0.08	0	No
Benzo(*k*)fluoranthene	mg/kg	4/ 86	0.55	0.07	0.35	0	No
Bis(2-ethylhexyl)phthalate	mg/kg	9/ 86	0.55	0.06	1.30	0	Yes
Butyl Benzyl Phthalate	mg/kg	1/ 86	0.57	0.05	0.05	0	No
Carbazole	mg/kg	1/ 86	0.57	0.07	0.07	0	No
Chrysene	mg/kg	10/ 86	0.55	0.05	0.94	0	Yes
Di-n-butyl Phthalate	mg/kg	2/ 86	0.65	0.17	8.30	0	No

Table 1-4. Site-related Contaminants in Sediment, EBG Phase I RI (continued)

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Fluoranthene	mg/kg	7/ 86	0.59	0.07	2.40	0	Yes
Fluorene	mg/kg	1/ 86	0.56	0.24	0.24	0	No
Indeno(1,2,3-*cd*)pyrene	mg/kg	2/ 86	0.56	0.08	0.28	0	No
N-Nitrosodiphenylamine	mg/kg	1/ 86	0.57	0.62	0.62	0	No
Phenanthrene	mg/kg	6/ 86	0.57	0.06	1.50	0	Yes
Phenol	mg/kg	1/ 86	0.57	0.16	0.16	0	No
Pyrene	mg/kg	9/ 86	0.57	0.05	1.20	0	Yes
Volatile Organic Constituents							
2-Butanone	mg/kg	10/ 16	0.02	0.01	0.10	0	Yes
Acetone	mg/kg	16/ 16	0.06	0.01	0.28	0	Yes
Benzene	mg/kg	1/ 16	0.01	0.002	0.002	0	Yes
Methylene Chloride	mg/kg	1/ 16	0.01	0.001	0.001	0	Yes
Toluene	mg/kg	8/ 16	0.01	0.01	0.05	0	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.

NA – Not applicable.

RI = Remedial investigation.

Table 1-5. Site-related Contaminants in Surface Water, EBG Phase I RI

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Explosives and Propellants							
1,3-Dinitrobenzene	µg/L	4/ 18	0.14	0.05	0.08	0	Yes
2,4,6-Trinitrotoluene	µg/L	3/ 18	0.22	0.05	1.10	0	Yes
2,4-Dinitrotoluene	µg/L	1/ 18	0.11	0.09	0.09	0	Yes
3-Nitrotoluene	µg/L	2/ 18	0.18	0.16	0.40	0	Yes
HMX	µg/L	2/ 18	1.69	0.09	0.41	0	Yes
Nitrobenzene	µg/L	1/ 18	0.14	0.07	0.07	0	Yes
Nitrocellulose as N	µg/L	1/ 18	281.70	820.00	820.00	0	Yes
Inorganics							
Aluminum	µg/L	15/ 18	26170.00	460.00	123000.00	3370.00	Yes
Antimony	µg/L	5/ 17	9.20	13.00	67.00	0.00	Yes
Arsenic	µg/L	18/ 18	27.41	3.70	120.00	3.20	Yes
Barium	µg/L	17/ 18	403.10	48.00	1900.00	47.50	Yes
Cadmium	µg/L	1/ 18	3.58	23.00	23.00	0.00	Yes
Calcium[b]	µg/L	17/ 17	51190.00	24200.00	114000.00	41400.00	No
Chromium	µg/L	7/ 14	34.93	19.00	150.00	0.00	Yes
Cobalt	µg/L	4/ 18	26.72	18.00	59.00	0.00	Yes
Copper	µg/L	11/ 15	93.92	5.00	630.00	7.90	Yes
Cyanide	µg/L	2/ 18	8.37	7.10	65.00	0.00	Yes
Iron[b]	µg/L	17/ 17	40740.00	430.00	197000.00	2560.00	No
Lead	µg/L	10/ 18	83.57	15.00	790.00	0.00	Yes
Magnesium[b]	µg/L	17/ 18	12860.00	7000.00	26800.00	10800.00	No
Manganese	µg/L	17/ 17	3416.00	310.00	11300.00	391.00	Yes
Mercury	µg/L	4/ 18	0.12	0.13	0.27	0.00	Yes
Nickel	µg/L	8/ 18	56.44	43.00	240.00	0.00	Yes
Potassium[b]	µg/L	18/ 18	14970.00	1400.00	42500.00	3170.00	No

Table 1-5. Site-related Contaminants in Surface Water, EBG Phase I RI (continued)

Analyte	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	Site Background Criteria	Site Related?
Selenium	µg/L	1/ 18	3.64	16.00	16.00	0.00	Yes
Sodium[b]	µg/L	16/ 16	24270.00	5700.00	50200.00	21300.00	No
Vanadium	µg/L	10/ 18	55.89	11.00	210.00	0.00	Yes
Zinc	µg/L	8/ 14	735.80	36.00	5400.00	42.00	Yes
Semivolatile Organic Constituents							
4-Methylphenol	µg/L	6/ 18	22.28	11.00	120.00	0	Yes
Phenol	µg/L	4/ 18	5.24	3.00	7.80	0	Yes
Volatile Organic Constituents							
Acetone	µg/L	6/ 18	6.73	6.10	13.00	0	Yes
Carbon Disulfide	µg/L	5/ 18	2.46	0.91	3.70	0	Yes
Chloroform	µg/L	3/ 18	2.19	0.54	0.71	0	Yes
Toluene	µg/L	7/ 18	1.82	0.49	1.10	0	Yes
Xylenes, Total	µg/L	1/ 18	2.46	1.70	1.70	0	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.
RI = Remedial investigation.

SRCs represent chemicals encountered in process wastes associated with open burning of explosives and explosive wastes. These SRCs, along with Phase II RI data, were further evaluated in the human health and ecological risk evaluations.

1.3.4 Erie Burning Grounds Phase II Remedial Investigation Data Quality Objectives

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

Soil. Surface soil samples were collected during the Phase II RI at EBG to further define contaminant nature and extent of surface soil contamination and to investigate potential source areas not sampled during Phase I. A total of 15 samples were collected; 5 were collected using the multi-increment sampling technique. Suspected source areas and contaminant accumulation points were targeted for biased soil sampling. Subsurface soils were obtained from monitoring well borings for the purpose of geotechnical analysis.

- **Sediment.** Twelve sediment samples, six discrete and six multi-increment, were obtained during the EBG Phase II RI, and all were subaqueous sediment from streams and ponds. Sediments were sampled from streams and ponds to: (1) assess the potential for contaminant migration via erosion to surface water and sediment; (2) evaluate potential contaminant accumulation areas, such as sedimentation basins and runoff collection points, (3) evaluate if residual contamination exists and if these areas could act as secondary sources for contamination; and (4) evaluate potential contaminant exit pathways from the AOCs.

- **Surface Water.** Eight surface water samples were obtained during the EBG Phase II RI. Water samples were collected from drainage ditches, streams, and ponds. The samples were analyzed to assess the potential for contaminant migration in surface water and to evaluate potential contaminant accumulation areas to evaluate if residual contamination is partitioning to water and if these features are acting as secondary sources for contamination to groundwater and surface water. In addition, the samples were analyzed to evaluate potential contaminant exit pathways from the AOC.

- **Groundwater.** Hydrogeologic and analytical data do not exist for groundwater at EBG. Because of the limited available data, contaminant migration from source areas to groundwater (via leaching or surface water infiltration) is an unknown element of the conceptual model at present. Considering the uncertainties associated with the CSM, the presence of groundwater contamination and potential migration pathways were evaluated as part of the Phase II RI. Groundwater characterization efforts included installation of eight wells to provide data on general hydrogeologic characteristics and groundwater flow patterns. Wells were installed in the vicinity of known surface soil and sediment contamination to evaluate whether contaminants are leaching to groundwater. Wells were also installed along the boundaries of EBG to determine whether groundwater and potential contaminant transport is occurring off of the AOC.

1.4 REPORT ORGANIZATION

This Phase II RI Report is organized to meet Ohio EPA requirements in accordance with U. S. Environmental Protection Agency (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 EBG. Chapter 2.0 describes the environmental setting at RVAAP and EBG, including the geology, hydrogeology, climate, population, and ecological resources. Chapter 3.0 describes the specific Phase II RI 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 II RI and discusses the occurrence and distribution of contamination at EBG. Chapter 5.0 presents the 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 the 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 II RI.

Appendices A through O to the Phase II RI Report for EBG contain supporting data collected during the Phase II RI. These appendices consist of soil sampling logs, sediment sampling logs, surface water sampling logs, a project quality assurance (QA) summary, a data quality assessment (DQA), analytical data, survey data, an ordnance and explosives (OE) avoidance survey report, an investigation-derived waste management report, and geotechnical analyses data used to make the interpretations presented herein. Data and calculations used in the fate and transport modeling and human health and ERAs are also included in the appendices.

2.0 ENVIRONMENTAL SETTING

This chapter describes the physical characteristics of EBG 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, hydrogeology, climate, and ecological characteristics of RVAAP were originally presented in Chapter 2.0 of the Phase I RI for EBG (USACE 2001c). The preliminary CSM for EBG presented at the end of this chapter is refined and updated in Chapter 8.0 based on site-specific data from the Phase II RI and local and regional information.

2.1 RVAAP PHYSIOGRAPHIC SETTING

RVAAP is located within the Southern New York Section of the Appalachian Plateau 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

EBG is situated in the northeastern corner of the RVAAP facility, as shown in Figure 1-2. Topography of EBG was mapped by USACE in 1998 on a 0.6-m (2-ft) contour interval, with an accuracy of 0.006 m (0.02 ft), from aerial photographs taken in 1997. This survey is the basis for topographic features presented in the figures in this Phase II RI Report. Topographic relief at EBG is very subdued. Elevations typically vary less than 0.9 m (3 ft) across the AOC, from approximately 285.9 to 287.2 m (938.1 to 942.4 ft) above mean sea level (amsl). The Track 49 embankment is elevated approximately 2.4 m (8 ft) relative to the pond’s surface.

Cultural features at EBG consist mainly of the gravel access road, train tracks, and man-made ditches that traverse or bound the AOC (see Figure 1-5). There are no buildings at EBG at present, and no evidence of permanent buildings in historical photos and drawings. Remnants of Track 49 still exist along the crest of the embankment, including railroad ties and miscellaneous associated metal debris (rail spikes, plates, etc.). During the low water conditions at the time of the Phase I RI (July and August 1999), pieces of formerly submerged wooden frame structures were observed in the vicinity of the former waste chute and burn area north of Track 49 (Figure 2-1).

2.3 REGIONAL 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 EBG are presented in the following subsections.

(View of the North Surface Water Basin from Track 49 to the North)

Figure 2-1. Site Conditions at the Erie Burning Grounds, November 2003

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 Ramsdell Quarry, and bedrock is present at or near the ground surface in many locations, such as Load Line 1 and Load 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.

According to the Ohio Department of Natural Resources (ODNR) (1982), EBG is situated within a band of glacial outwash deposits. These deposits extend due westward approximately 4.8 km (3 miles) from EBG and southeastward beyond the property boundary.

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 conglomerate unit thins to about 20 ft and in places may be missing, owing to non-deposition 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.

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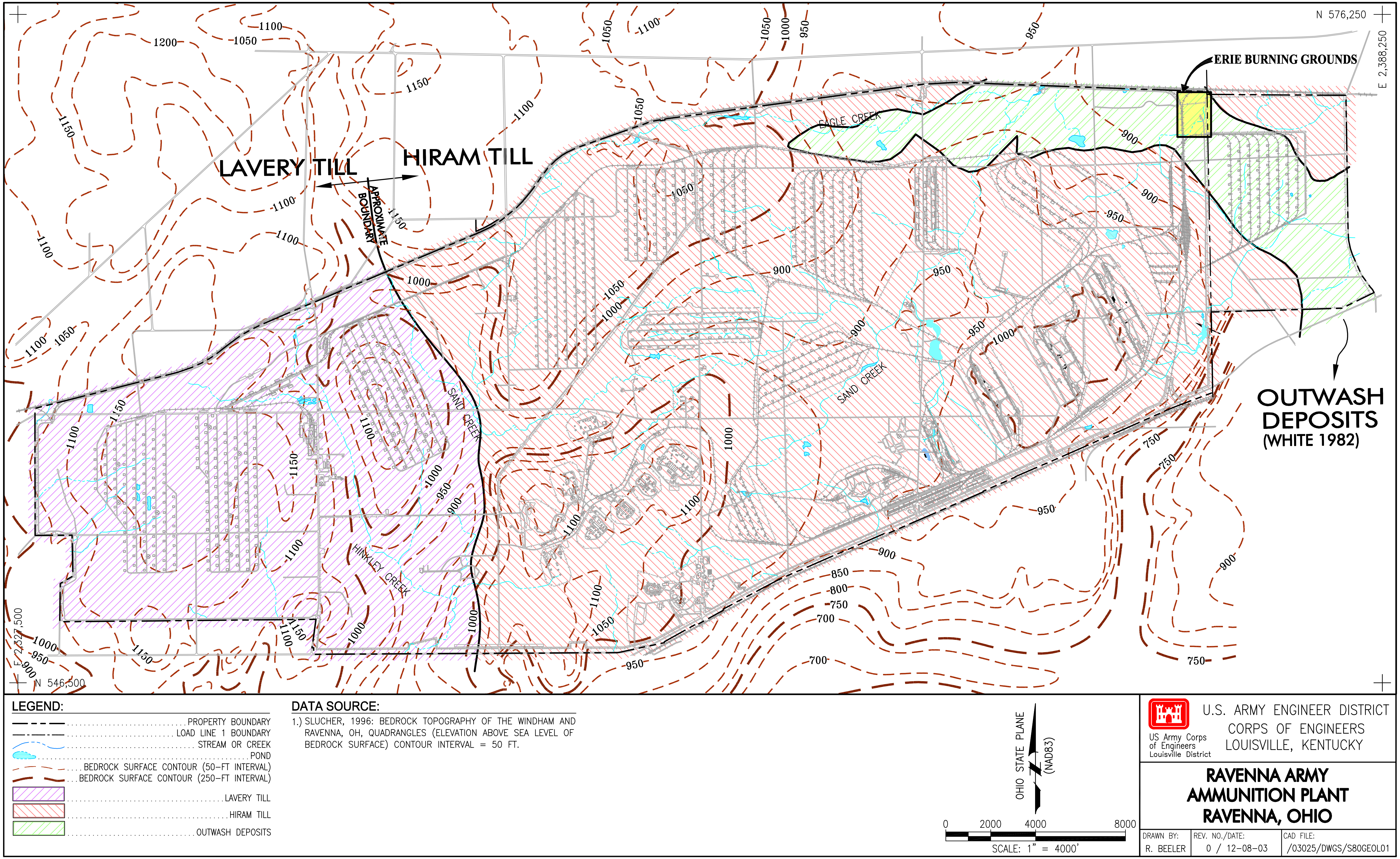


LEGEND:

- PROPERTY BOUNDARY
- LOAD LINE 1 BOUNDARY
- STREAM OR CREEK
- POND
- BEDROCK SURFACE CONTOUR (50–FT INTERVAL)
- BEDROCK SURFACE CONTOUR (250–FT INTERVAL)
- ▨ LAVERY TILL
- ▨ HIRAM TILL
- ▨ OUTWASH DEPOSITS

DATA SOURCE:

1.) SLUCHER, 1996: BEDROCK TOPOGRAPHY OF THE WINDHAM AND RAVENNA, OH, QUADRANGLES (ELEVATION ABOVE SEA LEVEL OF BEDROCK SURFACE) CONTOUR INTERVAL = 50 FT.

US Army Corps of Engineers
Louisville District

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

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	0 / 12-08-03	/03025/DWGS/S80GEOL01

Figure 2-2. Geologic Map of Unconsolidated Deposits on 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 Erie Burning Grounds

Deep borings or core holes were not drilled during the Phase I RI. However Phase II field activities included the installation of eight new groundwater monitoring wells intended to provide general data on the hydrogeological characteristics and groundwater flow patterns at EBG. Subsurface soil hand augering and lithologic logging to depths up to 0.9 m (3 ft) were performed at soil-sampling stations during the Phase I RI. Lithologic information from these borings is used to characterize the surface and subsurface geology of EBG and to refine a CSM. The limitations of these data are as follows:

- it is assumed that surface soil and sediment were substantially reworked in the course of preparation and use of the site as a burning ground; and

- bedrock was not penetrated in any of the soil or monitoring well borings.

2.3.2.1 EBG soils

At EBG, soils of the Sebring series silt loams are dominant. These soil types are associated with level to gently sloping, poorly drained soil of lacustrine or floodplain alluvial origin (USDA 1978). Native soil is derived from the weathering of glacial outwash or more recent alluvial material. Previous soil survey mapping indicates that surface soil varies in character from one surface feature to another. However, silty clays and silty sands dominate. The generic permeabilities of these soil types, as measured in the laboratory, range from 4.22×10^{-4} to 3.58×10^{-3} cm/sec (0.6 to 2.0 in./hr) in the upper 23 cm (9 in.) to 1.41×10^{-4} to 4.22×10^{-4} cm/sec (0.2 to 0.6 in./hr) below 23 cm (9 in.). Field descriptions of sediment collected at EBG include primarily silty clays and silts, in addition to black organic rich material at the sediment-water interface.

Soil types in the areas that were substantially reworked to prepare the area for use as an open burning ground (i.e., Track 49 area, borrow area, and access road) are sandy fill, sand, ballast material, and slag. Soil borings in some locations refused on sandstone cobbles and boulders, which comprised the fill and road base material in many locations at EBG. Soil along the edge of the access road was black to very dark brown clayey silts and silty clays on the surface. This soil graded at about 0.15 m (0.5 ft) to a black, moist, plastic clay, followed by a gray, stiff, plastic clay from 0.45 to 0.9 m (1.5 to 3.0 ft) bgs.

Lithologies encountered in the eight newly installed monitoring wells (total depth 25 to 32 ft bgs) include clay, silt, and fine sand. Several well borings (e.g., EBGmw-123 and EBGmw-125) were noted to contain possible fill material in the top 8 to 10 ft of the well boring.

2.3.2.2 EBG bedrock geology

Bedrock elevation data from monitoring wells installed as part of other CERCLA investigations closest to EBG (i.e., Ramsdell Quarry Landfill and Load Line 1; see Figure 1-2) indicate that the bedrock surface is comparatively shallow in this portion of the facility. However, no outcrops were observed at EBG, and no Phase II well borings [depths to 9.6 m (32 ft) bgs] penetrated bedrock.

2.4 REGIONAL HYDROLOGY

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 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 1.07×10^{-3} to 6.5×10^{-5} cm/sec. At Load Lines 4 and 12, unconsolidated zone hydraulic conductivities 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. Hydraulic conductivities of pervious zones below much less permeable surface layers at EBG located in the northeastern portion of RVAAP range from 2.89×10^{-1} to 8.13×10^{-4} 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 2003b). 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 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) 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, and the 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:

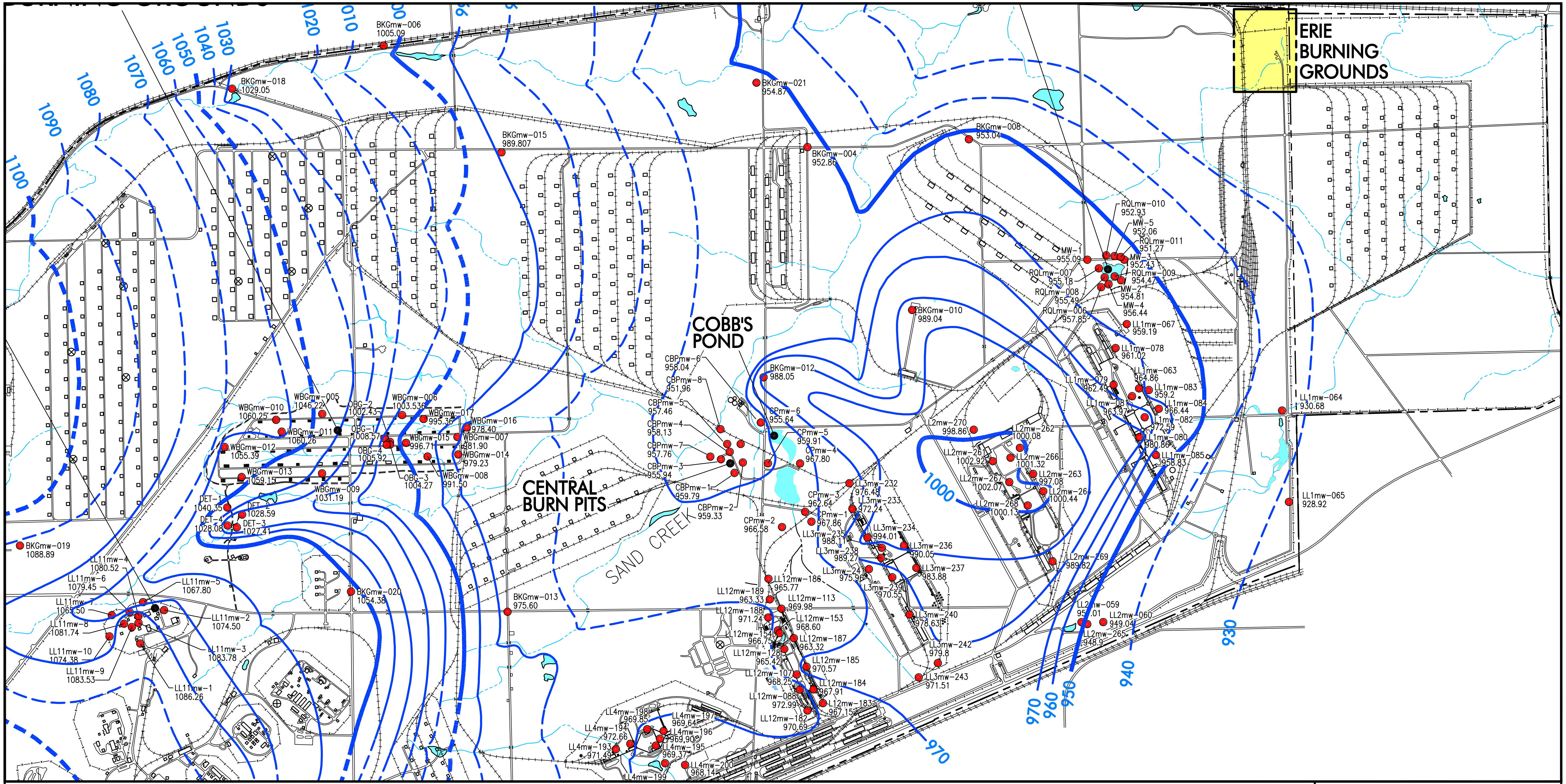
- a localized south-southeasterly flow component from the potentiometric high area centered around Load Lines 1, 2, and 3 toward the facility boundary;

- 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, and Load Lines 1 through 4). The potentiometric surface and water table gradients in the vicinity of Cobb’s Pond, Load Line 12, and Load Line 4 are



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.

OHIO STATE PLANE NAD 83

0 1250 2500 5000

SCALE: 1" = 2500'

US Army Corps of Engineers
Louisville District

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

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	0 / 12-08-03	/03025/DWGS/S80POTN01

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

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 are stocked with 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 Erie Burning Grounds Hydrologic/Hydrogeologic Setting

Eight new groundwater monitoring wells were installed at EBG during the Phase II RI with the intent to provide general data on the hydrogeologic characteristics and groundwater flow patterns at EBG. Figure 2-4 shows the potentiometric surface at EBG in November 2003.

Wells were installed to depths ranging from 25 ft bgs (EBGmw-125) to 32 ft bgs (EBGmw-123). Unconsolidated material consists of clay, silt, and fine sands (Appendix C). Several wells indicated fill or possible fill in the top 8 to 10 ft of the well borings (e.g., EBGmw-123 and EBGmw-125). These wells are located along the embankment for the rail road spur, and the fill or possible fill material was likely added to build up this area above the surrounding swampy areas.

Results of slug tests performed during the Phase II RI reveal moderately high horizontal hydraulic conductivities in the unconsolidated material underlying EBG. The wells at EBG show conductivities ranging from 2.89×10^{-1} to 8.13×10^{-4} cm/sec.

Surface water drainage flows from the north to the southwest across EBG. Surface water enters the site from the north along a drainage ditch and culvert pipe beneath Blackberry Lane. Although it is largely obscured flooding and vegetative cover, the trend of this ditch within EBG and extending north of the site boundary is still visible. Surface water drainage is also thought to enter EBG from the east through at least one culvert beneath Blackberry Lane. Surface water exits the pond at the southwest corner through a 120-cm (48-in.)-diameter reinforced concrete culvert beneath Track 10 at the southwest corner of the AOC. The AOC has been largely inundated since the early 1990s as a result of the subdued topography and beaver activity that blocked the former surface water drainage channel just downstream of the large culvert under Track 10 where it exits the site.

The surface water basins themselves are shallow and subject to seasonal fluctuations in water level. The water level in the ponds occasionally drops low enough so that no outflow occurs at the exit point as was evident during the Phase I field investigation. Seasonal high water may occasionally inundate much of the T-Area and access road. Sediment accumulations within the basins are greatest along the axis of the former drainage channel. Elsewhere in the ponds, a thin veneer of sediment overlies sandstone fill, construction debris, or other hard substrate. The nature and time of placement of these materials is not precisely known. Figure 2-2 shows conditions in the north surface water basin at the time of the Phase II RI field effort.

All surface water that exits EBG forms the headwaters of a perennial stream, which flows south then east and exits RVAAP immediately west of Route 534. Surface drainage from Load Line 1 also flows into this perennial stream, upstream of PF534. The tributary stream that exits EBG also passes near the strategic ore piles and intercepts a separate small tributary draining the ore piles upstream of PF534 (see Figure 1-2). Although these exit points are not within the AOC boundary proper, they were included in the Phase I RI to determine whether potential contamination is migrating beyond the boundary.

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 indicate 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 II RI was conducted during the historically dry portion of the year, but overall climate conditions tended to be wetter than normal.

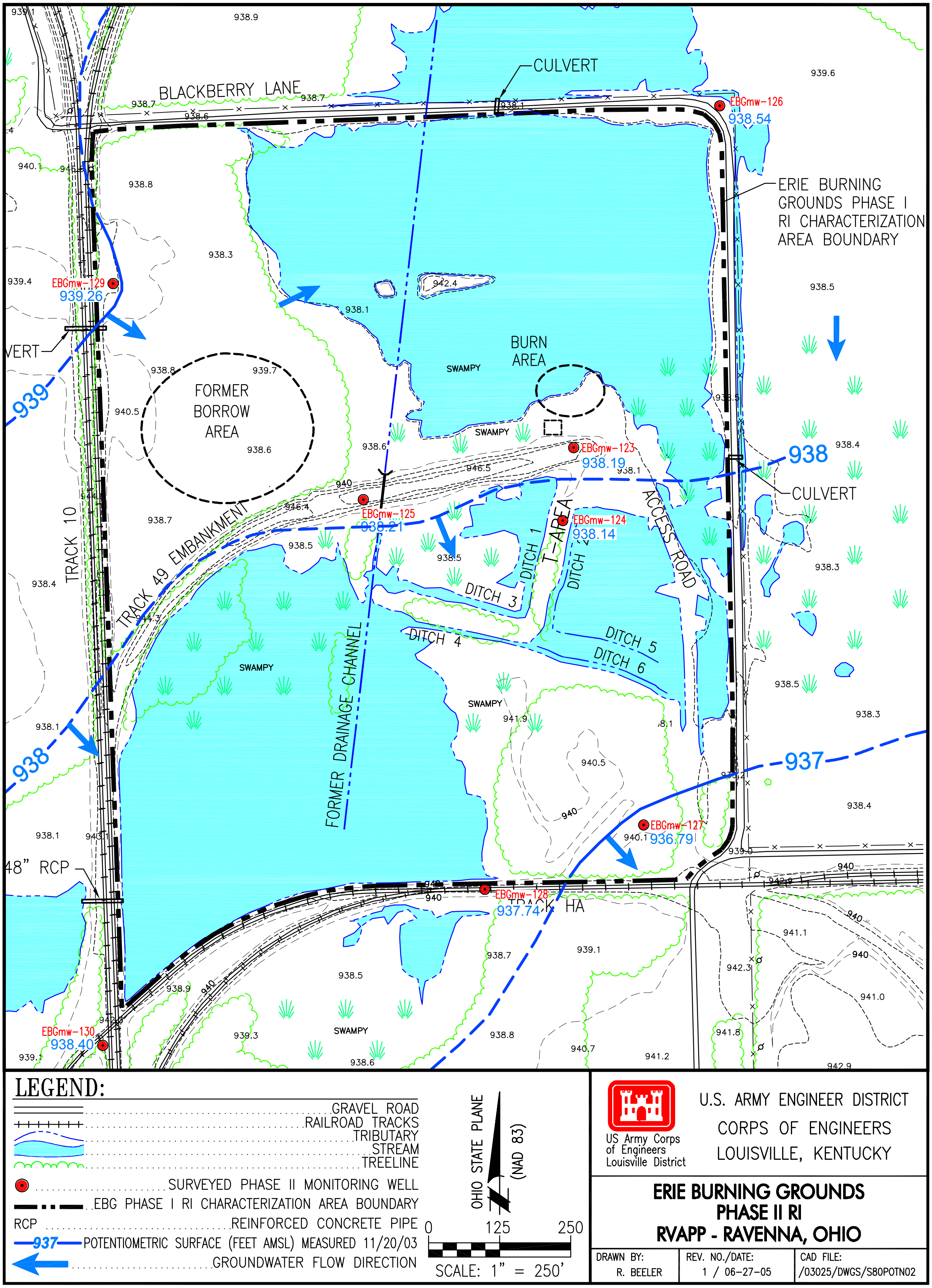


Figure 2-4. EBG Potentiometric Surface, November 2003

2.6 POTENTIAL RECEPTORS

2.6.1 Human Receptors

RVAAP consists of 8,668.3 ha (21,419 acres) and is located in northwestern 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. 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).

EBG is located in a remote portion of RVAAP and is not used for OHARNG training purposes. Industrial workers do not frequent the area because no facilities requiring maintenance or regular security checks are located on-site. Groundskeeping activities are limited to infrequent mowing. Security activities consist primarily of drivethrough surveillance along Blackberry Lane.

2.6.2 Ecological Receptors

The dominant types of vegetative cover at RVAAP 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. Non-inundated portions of EBG are forested (southeastern and northwestern corners of the site) or covered with extremely dense scrub vegetation as in the T-Area and Track 49 right of way. Hydrophytic vegetation exists throughout the wetland 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 (NWI) 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).

Wetland areas at RVAAP include seasonally saturated wetlands, wet fields, and forested wetlands. Most of these wetlands exist because of poorly drained and hydric soils. Beaver impoundments contribute to wetland diversification in some parts of the site, such as at EBG. High potential for negative impacts to wetlands exists simply because of the large areas of wetland. At EBG, wetland area covers or exists in close proximity to former operations areas.

The flora and fauna at RVAAP are varied and widespread. No federal threatened or endangered (T&E) or candidate T&E 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 2003). 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 T&E 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.

2.7 PRELIMINARY CONCEPTUAL SITE MODEL

The facility-wide hydrogeologic CSM for RVAAP presented in the Facility-wide SAP (USACE 2001a) is applicable to EBG for this Phase II RI based on current knowledge. The CSM for RVAAP, operational information, and data collected during the Phase I RI at EBG (USACE 2001c) were used to develop the preliminary EBG CSM, as outlined below. The preliminary CSM was used to develop sampling rationales and DQOs for the Phase II SAP Addendum (USACE 2003a). 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

Previous sampling data at EBG indicate that areas with the highest concentrations of explosives and metals contamination are primarily the Former Burn Area, the north side of the Track 49 embankment, and the north leg of the T-Area. Maximum values for aluminum, arsenic, chromium, and lead exceed both residential and industrial screening criteria by several orders of magnitude in these areas. Polycyclic aromatic hydrocarbons (PAHs) are prevalent throughout EBG and especially along Track 49. Eight PAHs had concentrations exceeding screening criteria or no criteria were available. Volatile organic compounds

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.

(VOCs) were not identified as COPCs in either the surface or subsurface soil. Soils at the Former Burn Area, the north side of Track 49, and the north leg of the T-Area are considered to be residual or secondary sources of contamination. Contaminant migration occurs via erosion of site soil to surface water bodies at the side through deposition of sediment or dissolution of more mobile contaminants.

Sediment

The north and east surface water basins appear to have received the bulk of contamination from runoff from the Former Burn Area, Track 49 embankment, and parking/staging area and, therefore, have the greatest concentrations of COPCs. The drainage channel that bisected the site prior to its inundation with water may have conveyed contaminants from north to south across the AOC. The south surface water basin and west leg of the T-Area contain few contaminants above background levels. Also, there were few contaminants detected above background at the surface water exit point at the southwest corner of EBG. This suggests that contaminants may not be migrating beyond the AOC boundary. Dilution, settling and sorption to organic matter, and biological uptake are possible means of isolating or attenuating contamination within the ponds at EBG. Contaminants showed the greatest exceedances of human health risk-based screening criteria along the northern side of the Track 49 embankment, gravel access road, and in ditches along the north leg of the T-Area closest to the Track 49 embankment. The human health COPCs include explosives, 11 metals, PCB-1254, and 3 PAHs. In the north surface water basin, PCB-1254 and explosives exceed risk based screening, and some metals exceeded both residential and industrial screening values by 2 to 100 times. Ecological COPCs in sediment include inorganics, semivolatile organic compounds (SVOCs), PCB-1254, and explosives, with 1,3,5-dinitrobenzene; 2,4-DNT; and 2,6-DNT exceeding their respective screening levels by large amounts.

Surface Water

In the Phase I RI, no explosives were detected above human health risk screening values within the AOC for surface water. However, two explosives (2,4,6-TNT and 2,4-DNT) were detected at off-site station PF534 at concentrations high enough to exceed human health risk screening values, and 2,4,6-TNT was also detected above its criteria at the east surface water inlet to EBG. Concentrations of inorganics above human health screening criteria primarily occur in the T-Area ditches. Four explosives were retained as ecological COPCs in the absence of any available screening criteria. Additionally, 17 metals, cyanide, 4-methylphenol, and carbon disulfide were detected above ecological risk screening values, with the T-Area ditches the primary locations of the maximum concentrations. Nitrobenzene was the only explosive or propellant compound detected in the samples from the EBG surface water exit point. The lack of detectable explosives at the EBG exit point indicates that the AOC is not the primary source of explosives contaminants observed at PF534. Also, the overall low levels of contaminants detected at the exit point suggest that the potential for attenuation by chemical and biological processes is high within the surface water system at EBG.

Groundwater

Hydrogeologic and analytical data were non-existent for groundwater at EBG prior to the Phase II RI. Therefore, general hydrogeologic characteristics and groundwater flow patterns were not known for the purposes of Phase II RI scoping. Because of the limited data, contaminant migration from source areas to groundwater (via leaching or surface water infiltration) had not been previously addressed.

Current Site Conditions

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. The RVAAP facility is located in a rural area and is not accessible to the general public. In addition, the entire facility is surrounded by a fence and patrolled by security personnel. However, both terrestrial and aquatic receptors are present and additional characterization and baseline risk assessments were conducted during the Phase II RI.

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3.0 STUDY AREA INVESTIGATION

The Phase II RI field effort conducted in October 2003 through January 2004 at EBG included sampling of surface soil, sediment, and surface water, as well as the installation, sampling, and slug testing of eight new monitoring wells. Subsurface soil sampling was conducted for geotechnical analysis only.

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 EBG Phase II RI (USACE 2003a). 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 2001a) and SAP Addendum No. 1 (USACE 2003a).

Proposed Phase II RI sample locations were reviewed by representatives of RVAAP, Ohio EPA, and USACE. 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 Phase II RI surface soil samples at EBG was intended to further define contaminant nature and extent of surface soil contamination and to investigate potential source areas not sampled during the Phase I RI. The Phase II RI employed biased, discrete samples to characterize suspected source areas and contaminant accumulation points. Additionally, multi-increment soil samples were collected from five areas to evaluate field application of this sampling method. Figure 3-1 illustrates locations of the discrete soil sampling locations for the Phase II 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 II RI.

3.1.1 Rationale

Surface soil sampling involved the combination of both discrete and multi-increment sampling to fill characterization data gaps remaining from the Phase I RI. Discrete surface soil samples were collected from the 0 to 1-ft interval at nine stations during the Phase II RI. Discrete sample data were collected to obtain the requisite data, along with Phase I RI results, to conduct risk evaluations. Ten discrete sample locations were originally planned in the Phase II RI SAP Addendum No. 1 (USACE 2003a). 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 II 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. Field conditions at the location of the planned surface soil sample station EBG-139 (Table 3-1) showed that the sample station was within an intermittent drainage conveyance leading to the northwestern exit culvert. Therefore, the location was reassigned as a sediment sample location. However, it is evaluated as a “dry sediment” sample and included in the surface soil aggregate data set for nature and extent (Chapter 4.0), as well as the human health (Chapter 6.0) and ecological (Chapter 7.0) risk assessments. The remaining nine surface soil locations were sampled as planned.

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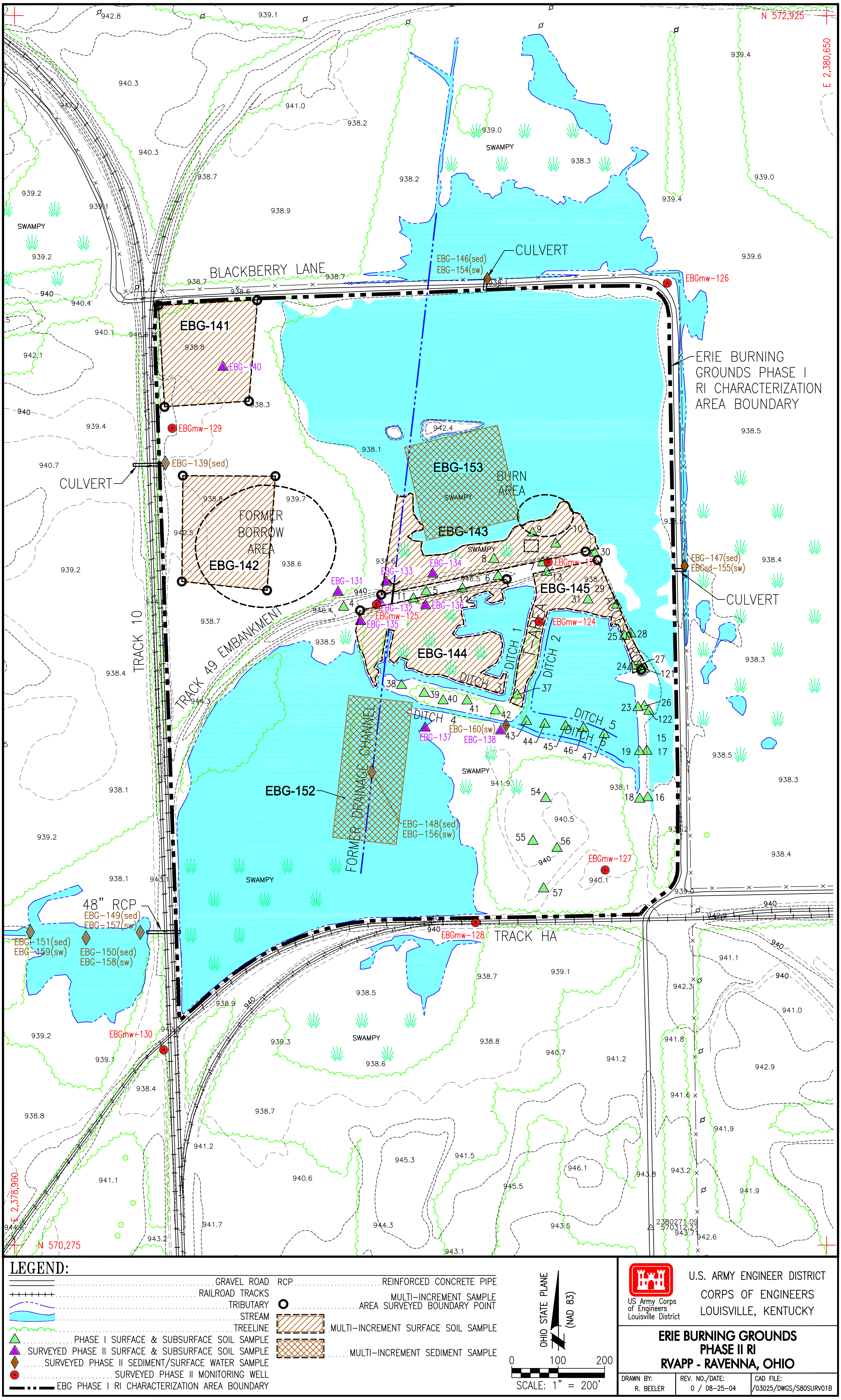

Figure 3-1. Sample Locations for EBG Phase II RI

Table 3-1. Soil Sample List and Rationales, Erie Burning Grounds Phase II RI

Facility/Area	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments/Rationales
Discrete Surface Soil Locations (nine)	0 to 1	EBG-131	EBGss-131-0291-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
	0 to 1	EBG-132	EBGss-132-0292-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
		EBG-132	EBGss-132-0330-SO	Y	10/28/2003	Field duplicate
		EBG-132	EBGss-132-0331-SO	Y	10/28/2003	QA split
	0 to 1	EBG-133	EBGss-133-0293-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
	0 to 1	EBG-134	EBGss-134-0294-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
	0 to 1	EBG-135	EBGss-135-0295-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
	0 to 1	EBG-136	EBGss-136-0296-SO	Y	10/28/2003	Additional characterization of Track 49 railbed and embankment
	0 to 1	EBG-137	EBGss-137-0297-SO	Y	10/28/2003	Observed metallic debris; melted material on the ground surface
	0 to 1	EBG-138	EBGss-138-0298-SO	Y	10/28/2003	South side of T-Area ditch, previously uncharacterized
	0 to 1	EBG-139	--	N	--	Standing water at location, reassigned as a sediment sample (See Table 3-2)[a]
	0 to 1	EBG-140	EBGss-140-0300-SO	Y	10/28/2003	Wooded area northwest corner of EBG, previously uncharacterized
Multi-Increment Surface Soil Locations (five)	0 to 1	EBG-141	EBGss-141-0301-SO	Y	10/30/2003	Wooded area northwest corner of EBG
	0 to 1	EBG-142	EBGss-142-0302-SO	Y	10/30/2003	Former Borrow Area
	0 to 1	EBG-143	EBGss-143-0303-SO	Y	11/03/2003	Track 49 north embankment area
	0 to 1	EBG-144	EBGss-144-0304-SO	Y	11/03/2003	Track 49 south embankment area
	0 to 1	EBG-145	EBGss-145-0305-SO	Y	10/31/2003	North leg of T-Area and northern portion of access road

[a] Although this sample location was under several inches of water at the time of collection, it is usually dry and, therefore, data were evaluated with the surface soil aggregate in Chapters 4.0, 6.0, and 7.0.

EBG = Erie Burning Grounds.
QA = Quality assurance.
RI = Remedial investigation.

The Phase II RI for EBG 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 II RI report.

3.1.2 Surface and Subsurface Soil Field Sampling Methods

Methods used for the collection of surface soil samples during the Phase II RI are summarized in the following sections. Detailed presentation of the procedures used to collect discrete soil samples is presented in the Phase II 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 II RI SAP Addendum No 1. Subsurface soils were collected during drilling of monitoring well borings using Shelby tubes for geotechnical analyses only.

3.1.2.1 Discrete soil samples

For discrete surface soil sampling stations, composite samples for laboratory analyses of explosives and propellants were collected. These composite samples were derived from three sub-samples, collected from approximately 3 ft from one another in a roughly equilateral triangle pattern. Samples for all discrete soil sample analyses other than explosives or propellants were collected from a point at the approximate center of the three triangular points from which the composite samples noted above were collected. 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 II RI. Samples for headspace analysis were not collected.

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. Samples for explosives, target analyte list (TAL) metals, and cyanide analyses were collected at all sample stations. Additionally, samples for propellants analyses were collected from three stations and samples for VOC and pesticide/polychlorinated biphenyl (PCB) analyses were collected at two stations. For explosives and propellants samples, the three soil sub-samples were placed into a decontaminated stainless steel bowl and thoroughly mixed with a decontaminated stainless steel spoon before collection into appropriate sample containers. Where specified, samples for VOCs were collected directly from the center sub-sample and placed directly into sample containers without mixing the soil. The remaining soil from the center sub-sample was placed into a decontaminated stainless steel bowl, mixed thoroughly, and samples for inorganics and non-volatile organics analyses placed into their appropriate sample containers. Results of discrete soil samples are discussed in Section 4.2.2, and are presented in their entirety in Appendix H.

3.1.2.2 Multi-increment soil samples

For purposes of multi-increment soil sampling, five distinct areas at EBG were identified for sample collection (Figure 3-1). Planned sampling areas as outlined in the EBG Phase II RI SAP Addendum No. 1 were refined in the field based on site conditions and accessibility. The boundaries of each area were roughly marked in the field with wooden stakes and/or 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 composite sample. The individual sample point at 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.

Multi-increment samples were analyzed for explosives, TAL metals, and cyanide. Field screening or headspace analysis for organic vapors was not conducted on multi-increment samples. Results of multi-increment samples are discussed in Section 4.2.3, and are presented in their entirety in Appendix H.

3.2 SEDIMENT CHARACTERIZATION

The Phase II RI employed biased, discrete samples to further investigate potential contaminant accumulation areas and, at selected locations, to evaluate any potential changes in contaminant concentrations over time since the Phase I RI in 1999. Additionally, triplicate multi-increment soil samples were collected from two separate areas to evaluate field application of this sampling method to characterization of subaqueous sediments. Figure 3-1 illustrates locations of the discrete soil sampling locations for the Phase II RI and shows the boundaries of each multi-increment sampling zone. Table 3-2 provides details on locations, rationales, sample depths, and other field information for all sediment sample collection activities during the Phase II RI.

3.2.1 Rationale

Discrete subaqueous sediment samples were collected at seven sample stations during the Phase II RI. Six stations were co-located with surface water samples. Four stations (EBG-146, -147, -150, and -151) were pre-planned. Stations EBG-146 and -147 were located at the upstream end of the north and east inlet pipes, respectively, that allow water to flow into EBG from off-post areas. These samples were intended to identify whether any contaminant flux was occurring into EBG from upstream areas. Stations WBG-150 and EBG-151 were located based on field conditions to characterize the stream channel downstream of the primary drainage culvert from EBG. Station EBG-148 was located in the field in the flooded drainage channel that bisects EBG, which was the primary drainage ditch at the time the burning grounds were operational, and represents a re-sampling of a potential contaminant accumulation area sampled during the Phase I RI. Station EBG-149, also located in the field, represents a re-sampling of the primary drainage culvert from the AOC. Station EBG-139, located at the head of the northernmost exit culvert from EBG, was planned as a soil station but reassigned as a sediment sample based on its location within an intermittent drainage conveyance.

Multi-increment sampling techniques were applied within two sampling areas to evaluate the field application of this sampling method to subaqueous sediments. Triplicate samples were collected from each of the two areas to examine reproducibility of results (total of six samples). Station EBG-152 was located in the area of the flooded drainage channel bisecting EBG downstream of Track 49 and the T-Area. Station EBG-153 was located adjacent to the Track 49 north embankment and Former Burn Area; this area was found to contain some of the highest concentrations of explosives in sediment samples collected during the Phase I RI.

Table 3-2. Sediment Sample List and Rationales, Erie Burning Grounds Phase II RI

Facility/Area	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments/Rationales
Discrete Sediment Locations (seven)	0 to 0.5	EBG-139	EBGsd-139-0299-SD	Y	10/29/2003	Changed from soil to sediment sample due to location within a drainage conveyance[a]
	0 to 0.5	EBG-146	EBGsd-146-0306-SD	Y	10/29/2003	Co-located with SW location EBG-154
	0 to 0.5	EBG-147	EBGsd-147-0307-SD	Y	10/29/2003	Co-located with SW location EBG-155
			EBGsd-147-0332-SD	Y	10/29/2003	Duplicate
			EBGsd-147-0333-SD	Y	10/29/2003	QA split
	0 to 0.5	EBG-148	EBGsd-148-0308-SD	Y	10/31/2003	Contingency, co-located with SW location EBG-156
	0 to 0.5	EBG-149	EBGsd-149-0309-SD	Y	10/30/2003	Contingency, co-located with SW location EBG-157
	0 to 0.5	EBG-150	EBGsd-150-0310-SD	Y	10/30/2003	Co-located with SW location EBG-158
	0 to 0.5	EBG-151	EBGsd-151-0311-SD	Y	10/30/2003	Co-located with SW location EBG-159
Multi-Increment Sediment Locations (two)	0 to 0.5	EBG-152	EBGsd-152-0312-SD EBGsd-152-0313-SD EBGsd-152-0314-SD	Y	10/31/2003	Multi-increment sampling area along primary drainage conveyance downstream of Track 49 and the T-Area
	0 to 0.5	EBG-153	EBGsd-153-0315-SD EBGsd-153-0316-SD EBGsd-153-0317-SD	Y	10/31/2003	Multi-increment sampling area along the primary drainage conveyance north of Track 49 and the Former Burn Area

[a] Although the area from which this sample was collected was wet at the time of sample collection, it is usually dry, and the data from EBG-139 were included in the surface soil aggregate.

QA = Quality assurance.

RI = Remedial investigation.

3.2.2 Sediment Field Sampling Methods

The methods used for the collection of discrete and multi-increment sediment samples during the Phase II RI are discussed in the following sections.

3.2.2.1 Discrete samples

Discrete sediment samples were collected using a decontaminated stainless steel, remotely operated clamshell sampler, stainless steel hand augers, and/or stainless steel scoops. Sample containers for VOC analyses were filled immediately with the initial sediment collected. Sample containers for the remaining analytes were then filled with the remaining homogenized sediment, as described in Section 4.5.2.5 of the Facility-wide SAP (USACE 2001a).

For co-located sediment and surface water sample locations, the surface water sample was collected prior to the sediment sample. Discrete sediment samples were analyzed for explosives, propellants, TAL metals, cyanide, pesticides/PCBs, VOCs, and TOC. Headspace analysis for organic vapors was not conducted on discrete sediment samples. Results of discrete sediment samples are discussed in Section 4.4.2 and are presented in their entirety in Appendix H.

3.2.2.2 Multi-increment samples

Multi-increment sediment samples were collected using decontaminated stainless steel hand augers and/or scoops. Multi-increment samples were collected as composite samples from multiple random points within each of the two designated areas. The aliquots comprising the sample were collected at random using the stainless steel hand auger. 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 composite sample. The individual sample points, at which each of the 30 aliquots was collected, were located at random while wading or from a boat employed in the field. Each sample aliquot was collected from the 0 to 0.5-ft interval.

Sample aliquots were composited in stainless steel bowls. The entire composited contents of each sample were mixed thoroughly and air-dried to the extent possible. It is noted that for samples containing a high moisture and clay or silt content, complete drying could not be obtained in a reasonable amount of time. After drying to the maximum practical extent, each sample was sieved using No. 4 and No. 10 brass sieves. Sieved samples were then spread onto aluminum trays for further drying. Once dry to the maximum practical extent, a minimum of 30 random aliquots was 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.

Multi-increment samples were analyzed for explosives, propellants, TAL metals, cyanide, and pesticides/PCBs. Headspace analysis for organic vapors was not conducted on multi-increment samples. Results of multi-increment sediment samples are discussed in Section 4.4.3 and are presented in their entirety Appendix H.

3.2.3 Surface Water Characterization

A total of eight surface water samples were collected during the Phase II RI at EBG. Six of the eight water samples were co-located with sediment samples collected at EBG. Table 3-3 provides details on

Table 3-3. Surface Water Sample List and Rationales, Erie Burning Grounds Phase II RI

Facility/Area	Depth (ft)	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments/Rationales
Surface Water Locations (eight)	NA	EBG-154	EBGsw-154-0318-SW	Y	10/29/2003	Co-located with SD location EBG-146
	NA	EBG-155	EBGsw-155-0319-SW	Y	10/29/2003	Co-located with SD location EBG-147
			EBGsw-155-0328-SW	Y	10/29/2003	Duplicate
			EBGsw-155-0329-SW	Y	10/29/2003	QA spilt
	NA	EBG-156	EBGsw-156-0320-SW	Y	10/31/2003	Co-located with SD location EBG-148
	NA	EBG-157	EBGsw-157-0321-SW	Y	10/30/2003	Contingency, co-located with SD location EBG-149
	NA	EBG-158	EBGsw-158-0322-SW	Y	10/30/2003	Co-located with SD location EBG-150
	NA	EBG-159	EBGsw-159-0323-SW	Y	10/30/2003	Co-located with SD location EBG-151
	NA	EBG-160	EBGsw-160-0324-SW	Y	10/30/2003	Contingency
	NA	EBG-161	EBGsw-161-0325-SW	Y	10/30/2003	Contingency, MS/MSD collected, PF534 location

MS/MSD = Matrix spike/matrix spike duplicate.
NA = Not applicable.
QA = Quality assurance.
RI = Remedial investigation.

locations, rationales, sample depths, and other field information for all surface water sample collection activities during the Phase II RI. Figure 3-1 illustrates locations of the eight surface water samples collected during the Phase II RI.

3.2.3.1 Rationale

Surface water samples were collected to assess the potential for contaminant occurrence in surface water, to evaluate potential contaminant accumulation areas to evaluate if residual contamination is partitioning to surface water, and to characterize the primary exit pathway for contaminants to migrate from the AOC. Five surface water samples were pre-planned (EBG-154, -155, -156, -158, and -159). Three sample stations were contingency stations located based on field conditions and data needs. Station EBG-157 was located at the main outlet pipe from EBG and station EBG-160 was located in the southernmost ditch bounding the T-Area. Both of these stations represent re-characterization of areas targeted during the Phase I RI. Conditions during the Phase I RI were extremely dry and surface water levels within EBG were very low and aquatic vegetation (e.g., algae) was dense. Consequently, some surface water samples collected at that time showed elevated levels of metals that may not reflect normal conditions. Thus, in accordance with recommendations from the Phase I RI, the follow-on phase of investigation included re-sampling of selected key locations to evaluate contaminant levels under normal rainfall conditions. The third contingency sample station, EBG-161, was collected from the eastern RVAAP facility boundary at PF534, located at State Route 534 (refer to Figure 1-2). This sample was collected to provide an additional temporal data point in the assessment potential of contaminant migration off of the facility via surface water flow.

3.2.4 Surface Water Field Sampling Methods

Surface water sampling was conducted in accordance with procedures outlined in Section 4.6.2.1 of the Facility-wide SAP (USACE 2001a). Sample containers were hand-filled by lowering the bottle into the water and allowing the bottle to fill, regulating the flow with the bottle cap, if necessary. All co-located surface water/sediment locations were sampled first for surface water to minimize the effects of sediment suspension on the surface water sample quality.

Surface water field measurements were performed to determine the pH, dissolved oxygen content, conductivity, and temperature of the collected sample, as described in Section 4.3.3 of the Facility-wide SAP (USACE 2001a). Surface water samples were not filtered prior to laboratory analysis. Results of surface water samples are discussed in Section 4.5 and are presented in their entirety in Appendix H.

3.3 GROUNDWATER CHARACTERIZATION

Prior to the EBG Phase II RI, hydrogeologic and analytical data were non-existent for groundwater at EBG. Accordingly, eight new groundwater monitoring wells were installed, sampled, and slug tested as part of the EBG Phase II RI to provide data on general hydrogeologic characteristics and groundwater flow patterns, and to assess groundwater impacts and potential migration pathways.

3.3.1 Rationale

Monitoring well locations were pre-planned, to the extent possible, to establish potentiometric gradients and to evaluate groundwater quality within or adjacent to former operations areas known to have the highest levels of soil and sediment contaminants based on the results of the Phase I RI. Table 3-4 provides monitoring well construction details for EBG Phase II RI monitoring wells. Table 3-5 provides the

Table 3-4. Summary of Erie Burning Grounds Monitoring Well Construction Data

Well ID	Total Depth (ft)	Elevation (GL)	Elevation (TOC)	Screened Interval (ft below GL)	Depth to Water (ft bgs)	Slug Test Hydraulic Conductivity (cm/sec)	Lithology in Screened Interval
EBGmw-123	32	945.59	947.82	21 to 31	9.5	2.0E-04	Clay with coarse sand/silt with fine sand
EBGmw-124	32	939.02	941.39	20 to 30	3.23	7.0E-04	Poor to medium-graded sand/silt
EBGmw-125	25	947.55	949.89	14 to 24	11.63	7.0E-03	Poorly graded fine to medium sand
EBGmw-126	28	938.20	940.61	15.17 to 25.17	2.05	3.0E-04	Finely graded silty sand
EBGmw-127	30	940.21	943.07	19 to 29	4.24	3.0E-05	Poor to well-graded sand and silt
EBGmw-128	28	942.47	945.13	15 to 25	6.33	1.0E-04	Silty clay to clayey silt
EBGmw-129	29	941.97	944.36	16 to 26	5.07	1.0E-03	Well-graded sand in upper half, poor in lower half
EBGmw-130	26	941.18	944.00	15.17 to 25.17	5.67	4.0E-034	Silty sand to silty clay

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

rationales for individual well locations. Three monitoring wells were located within the T-Area and along the crest of the Track 49 railroad embankment. Three wells were also located along the southern boundary of the AOC in the presumed downgradient direction from the former operations areas. Wells along the northern and western boundaries of the AOC were located in the presumed upgradient direction from the former operations areas to map the potentiometric surface.

3.3.2 Monitoring Well Installation Methods

Monitoring well installation was conducted in accordance with Section 4.1.2 of the EBG Phase II 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 drilling methods under the direct supervision of a qualified geologist. A 4.25-in., inside diameter, hollow-stem auger was employed with continuous soil sampling for geologic logging using a 2-ft-long, split-spoon sampler to the target depth. Bedrock was not encountered at any of the wells installed during the Phase II RI at EBG. Descriptions of soil stratigraphy were conducted in accordance with USCS using standard Munsell soil color charts. A total of six Shelby tube samples for geotechnical analyses were collected within the planned monitoring zones of five borings. Geotechnical results are discussed in Section 4.3.2, and presented in their entirety in Appendix I. 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.

Organic vapors were monitored during well installation from soil cuttings at each borehole using a hand held PID. Headspace readings of soil cuttings were not performed. Additionally, the breathing zone was monitored for evidence of organic vapors. No elevated PID readings were noted during the Phase II RI. All readings were recorded in the project logbooks.

Table 3-5. Groundwater Sample List and Rationales, Erie Burning Grounds Phase II RI

Facility/Area	Station	Sample ID	Sample Collected (Yes/No)	Date Sampled	Comments/Rationales
Groundwater Sample Locations (eight)	EBGmw-123	EBGmw-128-0283-GW	Y	11/25/2003	Source area characterization MS/MSD
	EBGmw-124	EBGmw-124-0284-GW	Y	11/25/2003	Source area characterization
	EBGmw-125	EBGmw-125-0285-GW	Y	11/21/2003	Source area characterization
	EBGmw-126	EBGmw-126-0286-GW	Y	11/20/2003	Upgradient, potentiometric surface assessment
		EBGmw-126-0326-GW	Y	11/20/2003	Duplicate
		EBGmw-126-0327-GW	Y	11/20/2003	QA split
	EBGmw-127	EBGmw-127-0287-GW	Y	12/01/2003	Downgradient, potentiometric surface assessment
	EBGmw-128	EBGmw-128-0288-GW	Y	11/24/2003	Downgradient, potentiometric surface assessment
	EBGmw-129	EBGmw-129-0289-GW	Y	11/24/2003	Upgradient, potentiometric surface assessment
	EBGmw-130	EBGmw-130-0290-GW	Y	11/20/2003	Downgradient, potentiometric surface assessment

MS/MSD = Matrix spike/matrix spike duplicate.

RI = Remedial investigation.

Following drilling of monitoring well boreholes to appropriate depths, monitoring wells were constructed from pre-cleaned, 2.0-in. inside diameter, schedule 40 polyvinyl chloride (PVC) pipe. Well screens were commercially fabricated with slot widths of 0.010 in. The wells were constructed using 10-ft screens. The well casing and screen were assembled and lowered into the open borehole. Following placement of the well screen, a filter pack consisting of #7 silica sand was tremied in to approximately 3 ft above the top of the well screen in each well. A 3- to 4-ft 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, followed by the placement of a protective steel surface casing and construction of a mortar collar and cement pad. Each pad was set with a small brass plate and the well identifier (ID) stamped into the plate. Four steel posts were installed around the pad of each well approximately 4 ft apart and painted for increased visibility in accordance with Section 4.3.2.3.9 of the Facility-wide SAP (USACE 2001a). Well construction diagrams, provided in Appendix B, summarize the construction details for the monitoring wells installed during the Phase II RI at EBG, including depths, screened intervals, and groundwater elevations. This information is summarized in Table 3-4.

3.3.3 Well Development Methods

Each new monitoring well was developed so that representative groundwater samples could be collected. Well development was accomplished with a pump, as per section 4.3.2.3.1.1 of the Facility-wide SAP. 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.

Additional volumes of water were required to be removed from two wells: EBGmw-128 and -129. During well construction, water was added to these boreholes to control heaving sands or to assist in placement of the sand pack. In addition to the criteria above, 5 times the water volume added during well drilling/construction was removed during development of these two wells (100 gal from EBGmw-128, and 175 gal from EBGmw-129). Records of all monitoring wells developed during the Phase II RI were kept on appropriate forms in field logbooks and are provided in Appendix B.

Following monitoring well development, water level measurements were taken at all eight wells in the EBG AOC. The potentiometric map utilizing these water level measurements is presented in Chapter 2.0 (Figure 2-4).

3.3.4 Groundwater Field Sampling Methods

Groundwater samples were collected from each of the eight 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. For all wells except EBGmw-127, micro-purge sampling techniques were employed using a portable bladder pump. Each monitoring well was purged using micro-purge methods until readings of pH, conductivity, and water temperature reached equilibrium. These general groundwater quality parameters were monitored continuously during sampling through use of a flow cell or similar device. Because of slow recharge at EBGmw-127, the well was sampled using a disposable bailer; the well was bailed dry, allowed to recover for no more than 24 hrs, and samples collected using the disposable bailer.

Wells were developed in accordance with work plan specifications to obtain the lowest turbidity readings possible. Micropurge sampling methods were employed for wells wherever possible. Despite these measures, turbidity levels remained above 5 NTUs in these 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.

Groundwater samples from EBG 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 a pre-sterilized, in-line, barrel filter with 0.45-um pores. For EBGmw-127, 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. The results of groundwater sampling are discussed in detail in Section 4.6, and presented in their entirety in Appendix H.

Table 3-5 provides details on locations, rationales, and sample identification for groundwater sample collection activities during the Phase II RI. Figure 3-1 illustrates the locations of the eight groundwater monitoring wells installed during the Phase II RI.

3.3.5 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 EBG RI. These analyses calculate horizontal hydraulic conductivities in the screened interval of each well. Falling and rising head slug tests were performed on each well. The falling head test was performed by rapidly inserting a PVC cylinder into the well and monitoring the return of the raised 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 fully recovered from groundwater sampling. The 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-Rice method. The results of slug tests are presented in Appendix E.

3.4 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 II RI SAP Addendum No. 1 for EBG.

3.4.1 Field Analyses for Explosives

No field analyses for explosives were conducted for the EBG Phase II RI.

3.4.2 Geotechnical Analyses

Geotechnical sampling and analysis conducted during the Phase II RI for EBG included both surface and subsurface soil. Discrete surface soil samples were analyzed for TOC by the primary analytical laboratory. A total of six undisturbed geotechnical samples (Shelby tubes) were obtained from five well borings, as shown in Table 3-6.

Table 3-6. Summary Geotechnical Samples, Erie Burning Grounds Phase II Remedial Investigation

Monitoring Well Boring	Shelby Tubes Collected	Depth Intervals (ft bgs)
EBGmw-124	1	18 to 20
EBGmw-125	1	22 to 24.5
EBGmw-128	2	16 to 18 22 to 24
EBGmw-129	1	20 to 22
EBGmw-130	1	24 to 24.7

bgs = Below ground surface.

Shelby tube samples were analyzed for Unified Soil Classification System (USCS) classification, Atterberg limits, bulk density, porosity, and TOC. Sampling procedures for geotechnical analyses followed methods presented in Section 4.5.2.4 of the Facility-wide SAP. The results of the geotechnical evaluations are summarized in Section 4.3.2, and can be found in their entirety in Appendix I.

3.4.3 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 II RI for EBG involved the collection and analysis of surface soil, sediment, surface water, and groundwater. Field screening for organic vapors was conducted at each sampling location using an organic vapor analyzer. All samples were analyzed by an independent laboratory under contract with USACE, Louisville District.

Samples collected during the investigation were analyzed by GPL Environmental, Inc. (GPL) of Gaithersburg, MD, a USACE Center of Excellence-certified laboratory. QA 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 EBG Phase II 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 II 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 1990). 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 3-7 presents a summary of QA/QC samples utilized during the Phase II RI. Evaluation of these QA/QC samples and their contribution to documenting the project data quality is provided in Appendix F.

Table 3-7. Summary of QA/QC Samples, Erie Burning Grounds Phase II 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 Matrix Spike/Matrix Spike Duplicate	Analyzed to assist in determining the analytical reproducibility and precision of the analysis for the samples of interest and to provide information about the effect of the sample matrix on the measurement methodology
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 retains all original raw data (both hardcopy and electronic) in a secure area under the custody of the laboratory project manager.

3.4.4 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.1 for the EBG Phase II 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 data set; comprehensive validation of the QA split sample data set; and a comparison of primary sample, field duplicate sample, and field QA split sample information.

3.5 ORDNANCE AND EXPLOSIVE AVOIDANCE AND FIELD RECONNAISSANCE

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

The OE 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 OE using visual surveys and hand-held magnetometers. The OE 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 OE technician. An OE technician remained with the sampling crews as work progressed.

For monitoring well borings, OE technicians screened the locations by hand augering to a minimum depth of at least 2 ft below the original undisturbed soil and performed downhole magnetometer readings at 2-ft intervals. The OE technician remained on-site as drilling was performed to visually examine drill cuttings for any unusual materials indicative of potential OE. The OE reconnaissance results at EBG are presented in Appendix L in their entirety.

4.0 NATURE AND EXTENT OF CONTAMINATION

This chapter presents results of the EBG Phase II RI data collected to further evaluate the nature and extent of contamination at EBG and to fill key data gaps remaining from the Phase I RI. Chemicals that are deemed to be related to AOC operations through the data screening process described below are classified as site-related contaminants (SRCs). These SRCs are then evaluated to determine their occurrence and distribution in environmental media at EBG. The data screened in this evaluation include only those from the Phase II RI investigation. Phase I RI data were screened as part of the Phase I RI (USACE 2001c) and are summarized by media at the beginning of each respective section.

For the purposes of this Phase II RI report, data aggregates were established based on environmental media (e.g., surface soil, sediment, surface water, and groundwater) and site operational history and physical characteristics (spatial aggregates). These data aggregates form the basis for exposure units (EUs) addressed in the human health and ecological risk evaluations (Chapters 6.0 and 7.0, respectively).

Section 4.1 of this chapter presents the statistical methods and facility-wide background screening criteria used to distinguish naturally occurring constituents present at ambient concentrations from SRCs indicative of impacts from historical site operations. Sections 4.2 through 4.6 present the nature and extent of identified SRCs within each of the data aggregates (e.g., surface soil, sediment, surface water, and groundwater) established for the purposes of this Phase II RI Report. Summary analytical results are presented in graphical or tabular formats in the sections addressing each data aggregate. Complete analytical results are contained within Appendix H. A summary of the results of the OE avoidance activities is presented in Section 4.7. Section 4.8 provides a comparative summary of the discrete and multi-increment samples.

4.1 DATA EVALUATION METHODS

The data evaluation methods for the EBG Phase II RI are consistent with those established under the Phase I and other investigations at RVAAP. These methods were described in the EBG Phase II RI SAP Addendum 1 (USACE 2003a). The processes used to evaluate the Phase II RI data included (1) determining chemical background concentrations, (2) defining data aggregates, and (3) data screening, which includes frequency of detection, comparison to background, and elimination of essential human nutrients to identify SRCs.

Some SRCs were identified at concentrations potentially posing a risk to human health or the environment based on additional risk screening processes discussed in Chapters 6.0 and 7.0. These SRCs are denoted as COPCs. The occurrence and distribution of those contaminants identified as COPCs are of particular interest and represent the focus of the assessments for each environmental media.

4.1.1 Site Chemical Background

Chemicals occur naturally in soils, sediments, surface water, and groundwater. The natural levels of chemicals—called background levels—must be known to determine whether the concentrations measured at a specific AOC are higher than would be expected if operations at that AOC had not occurred. Development of facility-wide background values for inorganic constituents in soil, sediment, surface water, and groundwater was conducted as part of a previous Phase II RI at WBG at RVAAP (USACE 2001c). These facility-wide background criteria have been reviewed and accepted by RVAAP, USACE, and Ohio EPA, and have been utilized in multiple RIs at RVAAP.

Although some organic compounds may also occur under ambient conditions (i.e., some PAHs), the organic compounds of primary concern (e.g., explosives) are man-made; therefore, background for all organic compounds was set to zero, and any detected concentration of these compounds is considered as being above background.

For each environmental medium of interest, a RVAAP facility-wide background level was calculated for each inorganic constituent 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 background data set, the data distributions were non-normal and 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.

The background criteria were set to zero for inorganic constituents that were not detected in the background samples. For those inorganic constituents that were not detected in the background samples, any detected result from the AOC would be considered above background. RVAAP facility-wide background criteria for each medium are listed in Table 4-1.

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

RVAAP = Ravenna Army Ammunition Plant.

4.1.2 Definition of Aggregates

The EBG data were grouped (aggregated) for evaluation of contaminant nature and extent. The aggregation of data for describing nature and extent is AOC-wide by environmental media: surface soil, sediment, surface water, and groundwater. Ecological risk evaluations (Chapter 7.0) also consider subsurface soil (1- to 3-ft depth) data obtained during the Phase I RI (see Section 1.3.3).

4.1.3 Data Reduction and Screening

4.1.3.1 Data verification and reduction

Analytical results were reported by the laboratory in electronic format and loaded into a database. 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 at the indicated concentration;
- "UJ" not detected, reporting limit estimated;
- "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 II RI data and 100% of the USACE QA laboratory data is performed by a third-party subcontractor to the USACE, Louisville District. Additional evaluation of the Phase II 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 minimum, maximum, and mean detected values and the proportion of detected results to the total number of samples collected. For calculation of mean detected values, non-detected results were addressed by using one-half of the reported detection limit as a surrogate value for 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 (Chapter 5.0) to identify contaminant migration contaminants of potential concern (CMCOPCs) 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, SVOCs, VOCs, 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 weight-of-evidence (WOE) approach was used to determine if the chemical was an 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 an SRC. For sample populations comprised of less than 20 samples, all detected constituents were carried forward to the facility-wide background and essential nutrient screening steps, as applicable.

All detected explosives and propellants were considered to be SRCs regardless of the frequency of detection and were subjected to nature and extent and risk evaluations. However, appropriate qualification is made in the assessment of occurrence and distribution for those explosives/propellants having a frequency of detection less than 5%.

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 an 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 as essential nutrients (i.e., 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 1989, 1996a) unless they are grossly elevated relative to background values. The essential nutrient screen is not applied as part of the ERA. For the EBG Phase II RI, chemical 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 each data aggregate are discussed in Sections 4.2 through 4.6. 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. Where only a few detected values for a class of SRCs occurred, the values are addressed in the text of the chapter. Complete Phase II analytical results, including all non-detected results, are contained in Appendix H. Complete results for the samples taken during the Phase I RI are listed in the report addressing that investigation (USACE 2001c).

Phase II samples were collected to further define the extent of contamination noted in the Phase I RI, and to facilitate evaluation of groundwater at EBG, which had not been done previously. The Phase I data are briefly summarized in the following sections, but the data are not presented again in detail in this report. Rather, the focus of the nature and extent evaluation was to present the results of the Phase II sample data with respect to the Phase I conclusions, and to focus the discussion on what additional information and conclusions are warranted by the evaluation of Phase II sample data. For completeness and ease of reference, combined Phase I and Phase II RI sample locations are indicated on Figure 3-1. Likewise, both Phase I and II RI results are presented on some figures for selected classes of contaminants (e.g., explosives in surface soil) to fully illustrate nature and extent.

A comparison of the SRCs identified from the Phase I RI and those identified for the Phase II RI was conducted. New SRCs were identified from the Phase II RI data and are summarized below.

Surface soil

Six new SRCs were identified based on the screening of the Phase II surface soil data. These include:

- 2,6-DNT;
- 2-amino-4,6-DNT;
- 4-amino-2,6-DNT;
- RDX;
- naphthalene; and
- toluene.

Sediment

Screening of the Phase II RI data identified two new SRCs:

- beryllium, and
- methoxychlor.

Surface water

No new SRCs were identified in the screening of the Phase II RI surface water data.

Groundwater

Because groundwater at EBG had not previously been sampled, no groundwater SRCs had been previously identified.

4.1.5 Use of Phase I Remedial Investigation Data

EBG remained relatively undisturbed between the Phase I and Phase II RIs. Accordingly, soil data obtained during the Phase I RI in 1999 were deemed to still represent current conditions at the AOC for the purposes of calculating human health and ecological risk. Thus, Phase I RI soil data are incorporated into the quantitative fate and transport and risk evaluations. Dry sediment samples collected during the Phase I RI were collected from the 0 to 0.5-ft bgs interval; these were assigned as surface soil aggregate samples in the risk evaluations. Sediment data collected from streams and ponds during the Phase I RI were also used in COPC determination and risk evaluations. Phase I RI surface water results were also incorporated in quantitative risk evaluations along with Phase II results to represent the range of observed conditions (dry, low pool and wet, high pool) that may occur within the EBG impoundments.

4.2 SURFACE SOILS

4.2.1 Summary of Phase I Remedial Investigation Data

Based on the analytical results for surface soil samples collected during the Phase I RI, the following summarizes the key nature and extent findings for surface soils at EBG.

- Explosives in surface soils occur along the Track 49 embankment, the gravel access road, at isolated locations on the north and east legs of the T-Area, the Former Borrow Area, and the Former Burn Area. No explosives were found in the wooded area south of the T-Area or on the west leg of the T-Area. The compound 2,4,6-TNT was the most pervasive explosive detected in surface soil. The maximum concentration of 2,4,6-TNT was 7.1 mg/kg in the Track 49 embankment area. The propellant nitrocellulose was detected in four surface soil samples, with no apparent pattern of distribution.

- Inorganics are pervasive in surface soil. Aluminum, arsenic, chromium, manganese, nickel, and vanadium were detected in 100% of the surface soil samples, but they occurred above background in less than about 30%. Barium, copper, lead, and zinc were detected in 100% of the samples and were above background in at least 50% of the samples. Antimony and mercury were detected about 30% of the time, but nearly all detects exceeded background. The highest concentrations are associated with the Former Burn Area, Track 49 embankment, and T-Area.

- SVOC contamination was primarily due to bis(2-ethylhexyl)phthalate and was limited to the wooded area south of the T-Area and gravel access road. PAHs were detected along the Track 49 embankment, the gravel access road, and the north leg of the T-Area. VOCs (acetone and methylene chloride) were sporadically detected. PCB compounds were not detected.

4.2.2 Discrete Samples

Surface soil samples were collected from nine discrete locations during the EBG Phase II RI to further define surface soil contaminant nature and extent and to investigate potential source areas not sampled during the Phase I RI. In addition, one planned discrete surface soil sample (EBG-139) was re-classified as a sediment sample when collected due to its location in a drainage conveyance that is dry for most of the year. Therefore, this sample was included in the surface soil aggregate. All discrete samples were analyzed for explosives, TAL metals, cyanide, and SVOCs. Three discrete surface soil samples were analyzed for propellants and two discrete samples were analyzed for pesticides/PCBs and VOCs. Data summary statistics and screening results to identify SRCs are presented in Table 4-2.

4.2.2.1 Explosives and propellants

Five explosive and propellant compounds were detected in the EBG discrete surface soil samples. Four of the five (all except 2,4,6-TNT) had not been detected previously in Phase I surface soil samples. Explosives and propellants were detected at sample locations EBG-131, -133, and -134 located on the north side of the Track 49 embankment and locations EBG-132, -135, and -136 along the south side of the embankment (Figure 4-1). Analytical results for these samples are presented in Table 4-3.

Table 4-2. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Grounds Surface Soil

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL$_{95}$ of Mean	Exposure Concentration	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Explosives											
2,4,6-Trinitrotoluene	118-96-7	mg/kg	4/ 10	2.49E-01	8.60E-02	1.70E+00	5.47E-01	5.47E-01	0	Yes	Yes
2,6-Dinitrotoluene	606-20-2	mg/kg	1/ 10	5.50E-02	1.00E-01	1.00E-01	6.42E-02	6.42E-02	0	Yes	Yes
2-Amino-4,6-dinitrotoluene	35572-78-2	mg/kg	5/ 10	6.59E-02	2.70E-02	1.30E-01	9.32E-02	9.32E-02	0	Yes	Yes
4-Amino-2,6-dinitrotoluene	19406-51-0	mg/kg	5/ 10	7.58E-02	5.80E-02	1.70E-01	1.00E-01	1.00E-01	0	Yes	Yes
RDX	121-82-4	mg/kg	2/ 10	2.16E-01	6.30E-01	7.30E-01	3.58E-01	3.58E-01	0	Yes	Yes
Metals											
Aluminum	7429-90-5	mg/kg	10/ 10	1.49E+04	5.49E+03	2.52E+04	1.89E+04	1.89E+04	1.77E+04	Yes	Yes
Antimony	7440-36-0	mg/kg	9/ 10	3.79E+00	1.20E-01	1.90E+01	6.74E+02	1.90E+01	9.60E-01	Yes	Yes
Arsenic	7440-38-2	mg/kg	10/ 10	1.15E+01	1.10E+00	2.56E+01	1.61E+01	1.61E+01	1.54E+01	Yes	Yes
Barium	7440-39-3	mg/kg	10/ 10	5.46E+02	5.38E+01	1.76E+03	4.86E+03	1.76E+03	8.84E+01	Yes	Yes
Beryllium	7440-41-7	mg/kg	10/ 10	5.52E-01	2.40E-01	9.30E-01	6.78E-01	6.78E-01	8.80E-01	Yes	Yes
Cadmium	7440-43-9	mg/kg	10/ 10	2.12E+00	1.30E-01	8.30E+00	1.97E+01	8.30E+00	0	Yes	Yes
Calcium	7440-70-2	mg/kg	10/ 10	7.00E+03	8.27E+02	1.68E+04	1.04E+04	1.04E+04	1.58E+04	Yes	No
Chromium	7440-47-3	mg/kg	10/ 10	3.81E+01	7.30E+00	1.02E+02	9.68E+01	9.68E+01	1.74E+01	Yes	Yes
Cobalt	7440-48-4	mg/kg	10/ 10	8.79E+00	1.60E+00	1.82E+01	1.19E+01	1.19E+01	1.04E+01	Yes	Yes
Copper	7440-50-8	mg/kg	10/ 10	1.70E+02	5.00E+00	5.59E+02	4.49E+03	5.59E+02	1.77E+01	Yes	Yes
Cyanide	57-12-5	mg/kg	2/ 10	1.78E-01	2.60E-01	6.40E-01	2.77E-01	2.77E-01	0	Yes	Yes
Iron	7439-89-6	mg/kg	10/ 10	4.25E+04	4.42E+03	1.52E+05	2.03E+05	1.52E+05	2.31E+04	Yes	No
Lead	7439-92-1	mg/kg	10/ 10	3.34E+02	1.02E+01	1.18E+03	1.81E+04	1.18E+03	2.61E+01	Yes	Yes
Magnesium	7439-95-4	mg/kg	10/ 10	4.80E+03	6.76E+02	2.28E+04	1.18E+04	1.18E+04	3.03E+03	Yes	No
Manganese	7439-96-5	mg/kg	10/ 10	5.57E+02	1.77E+01	1.47E+03	8.45E+02	8.45E+02	1.45E+03	Yes	Yes
Mercury	7439-97-6	mg/kg	9/ 10	3.51E-02	1.80E-02	7.00E-02	6.12E-02	6.12E-02	3.60E-02	Yes	Yes
Nickel	7440-02-0	mg/kg	10/ 10	3.37E+01	6.30E+00	1.21E+02	9.97E+01	9.97E+01	2.11E+01	Yes	Yes
Potassium	7440-09-7	mg/kg	10/ 10	1.35E+03	2.53E+02	2.42E+03	1.82E+03	1.82E+03	9.27E+02	Yes	No
Silver	7440-22-4	mg/kg	6/ 10	2.28E+00	7.70E-02	8.70E+00	4.02E+00	4.02E+00	0	Yes	Yes
Sodium	7440-23-5	mg/kg	10/ 10	6.33E+02	3.03E+01	2.51E+03	1.50E+04	2.51E+03	1.23E+02	Yes	No
Thallium	7440-28-0	mg/kg	4/ 10	1.81E-01	2.40E-01	3.80E-01	2.60E-01	2.60E-01	0	Yes	Yes
Vanadium	7440-62-2	mg/kg	10/ 10	3.03E+01	8.20E+00	6.51E+01	4.13E+01	4.13E+01	3.11E+01	Yes	Yes
Zinc	7440-66-6	mg/kg	10/ 10	1.03E+03	1.63E+01	4.06E+03	1.98E+05	4.06E+03	6.18E+01	Yes	Yes

Table 4-2. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Grounds Surface Soil (continued)

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL$_{95}$ of Mean	Exposure Concentration	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Miscellaneous											
Total Organic Carbon	N997	%	1/ 1	6.90E-01	6.90E-01	6.90E-01		6.90E-01	NA	NA	NA
Organics-Semivolatile											
2-Methylnaphthalene	91-57-6	mg/kg	2/ 10	2.19E-01	4.80E-02	6.30E-02	2.76E-01	6.30E-02	0	Yes	Yes
Anthracene	120-12-7	mg/kg	1/ 10	2.39E-01	7.70E-02	7.70E-02	2.82E-01	7.70E-02	0	Yes	Yes
Benz(*a*)anthracene	56-55-3	mg/kg	2/ 10	2.60E-01	1.30E-01	3.60E-01	3.01E-01	3.01E-01	0	Yes	Yes
Benzo(*a*)pyrene	50-32-8	mg/kg	3/ 10	2.42E-01	1.20E-01	3.10E-01	2.87E-01	2.87E-01	0	Yes	Yes
Benzo(*b*)fluoranthene	205-99-2	mg/kg	4/ 10	3.09E-01	2.00E-01	7.60E-01	4.05E-01	4.05E-01	0	Yes	Yes
Benzo(*g,h,i*)perylene	191-24-2	mg/kg	5/ 10	1.83E-01	8.10E-02	2.00E-01	2.28E-01	2.00E-01	0	Yes	Yes
Benzo(*k*)fluoranthene	207-08-9	mg/kg	3/ 10	2.28E-01	9.80E-02	2.20E-01	2.76E-01	2.20E-01	0	Yes	Yes
Bis(2-ethylhexyl)phthalate	117-81-7	mg/kg	4/ 10	2.95E-01	7.90E-02	7.80E-01	4.12E-01	4.12E-01	0	Yes	Yes
Chrysene	218-01-9	mg/kg	4/ 10	2.44E-01	1.20E-01	4.50E-01	3.02E-01	3.02E-01	0	Yes	Yes
Dibenz(*a,h*)anthracene	53-70-3	mg/kg	1/ 10	2.36E-01	5.10E-02	5.10E-02	2.83E-01	5.10E-02	0	Yes	Yes
Fluoranthene	206-44-0	mg/kg	5/ 10	1.90E-01	8.10E-02	2.70E-01	2.39E-01	2.39E-01	0	Yes	Yes
Indeno(1,2,3-*cd*)pyrene	193-39-5	mg/kg	3/ 10	2.25E-01	8.40E-02	1.60E-01	2.73E-01	1.60E-01	0	Yes	Yes
Naphthalene	91-20-3	mg/kg	2/ 10	2.16E-01	6.90E-02	1.00E-01	2.63E-01	1.00E-01	0	Yes	Yes
Phenanthrene	85-01-8	mg/kg	3/ 10	2.02E-01	5.40E-02	1.20E-01	2.54E-01	1.20E-01	0	Yes	Yes
Pyrene	129-00-0	mg/kg	3/ 10	2.42E-01	1.20E-01	3.00E-01	2.79E-01	2.79E-01	0	Yes	Yes
Organics-Volatile											
Toluene	108-88-3	mg/kg	2/ 2	3.45E-03	2.90E-03	4.00E-03	6.92E-03	4.00E-03	0	Yes	Yes

[a] One-half of the detection limit was used as a surrogate value for non-detects in the calculation of summary statistics.
[b] Background criteria were set to zero for all organics and inorganics that were not detected in the background data set.
[c] The essential nutrient screen was not applied for the ecological risk assessment.
CAS = Chemical Abstracts Service.
NA = Not applicable.
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
SRC = Site-related contaminant.
UCL95 = 95% Upper confidence limit.

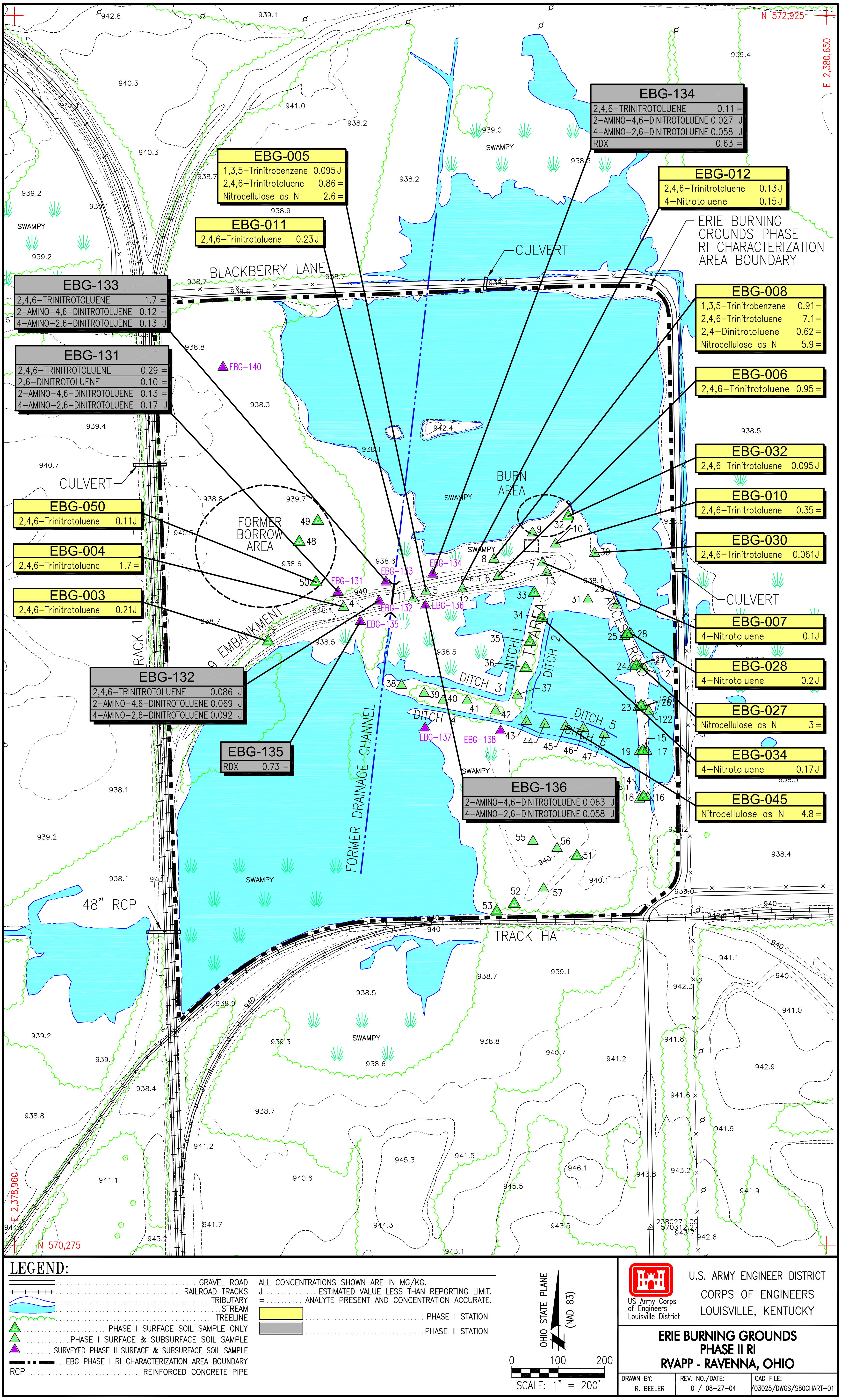

Figure 4-1. Occurrence of Explosives and Propellants in Surface Soil, EBG Phase I and II RI

Table 4-3. Explosive and Propellant SRCs in Phase II RI Discrete Surface Soil Samples

Analyte (mg/kg)	Station					
	EBG-131	EBG-132	EBG-133	EBG-134	EBG-135	EBG-136
2,4,6-Trinitrotoluene	0.29 =	0.086 J	1.7 =	0.11 =		
2,6-Dinitrotoluene	0.1 =					
2-Amino-4,6-dinitrotoluene	0.13 =	0.069 J	0.12 =	0.027 J		0.063 J
4-Amino-2,6-dinitrotoluene	0.17 J	0.092 J	0.13 J	0.058 J		0.058 J
RDX				0.63 =	0.73 =	

RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine.
RI = Remedial investigation.
SRC = Site-related contaminant.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

Phase II sampling indicates that the occurrence of explosives in surface soils extends further out from the center of the Track 49 embankment than previously thought, particularly on the north side of the embankment. 2,4,6-TNT is the only explosive compound that was detected during both the Phase I and II investigations, it was present in the three Phase II locations on the north side of the embankment and one of the three stations on the south side of the embankment (Figure 4-2). Concentrations were lower than the maximum Phase I concentration of 7.1 mg/kg on the Track 49 embankment (station EBG-008). Explosives were not detected in the Phase II samples in the wooded area south of the T-Area or in the northwest section of EBG.

4.2.2.2 Inorganic constituents

Twenty-three inorganic constituents were detected in surface soil samples collected during the Phase II RI (Table 4-2). Eighteen of these constituents were identified as SRCs. The constituents eliminated as surface soil SRCs were the essential nutrients calcium, iron, magnesium, potassium, and sodium. Four of the 18 constituents were considered SRCs because background criteria are zero (cadmium, cyanide, silver, and thallium). Results of the Phase II RI for inorganic constituents in surface soil are presented in Table 4-4.

Aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc were detected at all Phase II sampling locations. Cadmium exceeded background at all locations. At three locations (EBG-137, -138, and -140), cadmium was the only metal that exceeded its background criteria (zero). With the exception of cadmium, the most pervasive inorganic constituents in Phase II samples were barium, copper, and nickel, all of which exceeded background concentrations at seven sample locations. Figure 4-2 illustrates results for selected SRCs prevalent in Phase II RI soil samples.

Sample locations EBG-134 and -136 located near the center of the AOC on the north and south sides of the Track 49 embankment had the highest number of constituents exceeding background concentrations (14). The sample locations with the lowest number of inorganic constituents exceeding background concentrations (one inorganic SRC) were EBG-137 and -138 located south of Ditch 4 in the T-Area and EBG-140 located north of the Former Borrow Area.

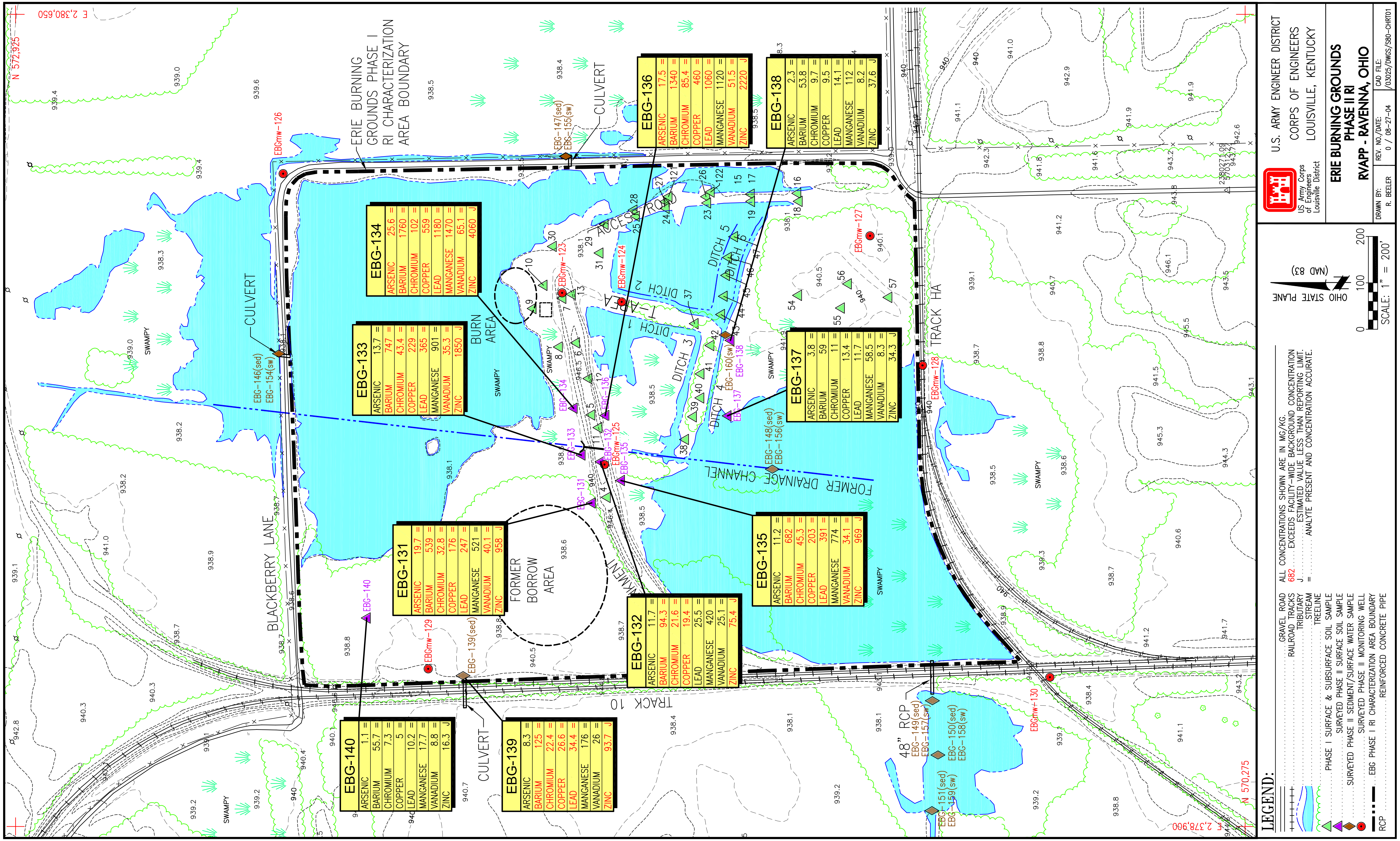

Figure 4-2. Occurrence of Selected Inorganic SRCs in Surface Soil, EBG Phase II RI

Table 4-4. Inorganic SRCs in Phase II RI Discrete Surface Soil Samples

Analyte (mg/kg)	Station									
	EBG-131	EBG-132	EBG-133	EBG-134	EBG-135	EBG-136	EBG-137	EBG-138	EBG-139	EBG-140
Aluminum	16,000 =	14,800 =	16,600 =	25,200= *	17,300 =	23,900 = *	5,490 =	5,630 =	16,500 =	7,120 =
Antimony	1.4 J *	0.67 J	4.8 J *	19 J *	2.8 J *	8.7 J *	0.13 J	0.25 J	0.12 J	
Arsenic	19.7 = *	11.7 =	13.7 =	25.6 = *	11.2 =	17.5 = *	3.8 =	2.3 =	8.3 =	1.1 =
Barium	539 = *	94.3 = *	747 = *	1,760= *	682= *	1,340 = *	59 =	53.8 =	125 = *	55.7 =
Beryllium	0.59 =	0.72 =	0.76 =	0.65 =	0.47 =	0.47 =	0.24 =	0.29 =	0.93 = *	0.4 =
Cadmium	1.4 = *	0.42 = *	3.1 = *	8.3 = *	2.1 = *	4.8 = *	0.27 = *	0.2 J *	0.49 = *	0.13 J *
Chromium	32.8 = *	21.6 = *	43.4 = *	102= *	45.3= *	85.4 = *	11 =	9.7 =	22.4 = *	7.3 =
Cobalt	10.9 = *	10.7 = *	10.9 = *	18.2= *	8.6 =	12.9 = *	1.6 =	1.9 =	9.5 =	2.7 =
Copper	176 = *	19.4 = *	229 = *	559= *	203= *	460 = *	13.4 =	9.5 =	26.6 = *	5 =
Cyanide		0.64 J *	0.26 J *							
Lead	247 = *	25.5 =	365 = *	1,180= *	391= *	1,060 = *	11.7 =	14.1 =	34.4 = *	10.2 =
Manganese	521 =	420 =	901 =	1,470= *	774 =	1,120 =	58.5 =	112 =	176 =	17.7 =
Mercury		0.019 J	0.035 J	0.058 J *	0.034 J	0.07 J *	0.018 J	0.023 J	0.061 J *	0.023 J
Nickel	25.3 = *	24.1 = *	42.2 = *	121= *	29.3= *	51.1 = *	6.3 =	6.7 =	24.5 = *	6.4 =
Silver	2.4 = *	0.077 J *	2.2 = *	8.7= *	3.3 = *	6 = *				
Thallium	0.24 J *	0.34 J *			0.38 J *				0.37 J *	
Vanadium	40.1 = *	25.1 =	35.3 = *	65.1= *	34.1= *	51.5 = *	8.3 =	8.2 =	26 =	8.8 =
Zinc	958 J *	75.4 J *	1,850 J *	4,060 J *	969 J *	2,220 J *	34.3 J	37.6 J	93.7 J *	16.3 J

RI = Remedial investigation.
SRC = Site-related contaminant.
* - value above facility-wide background criterion.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

The Phase II inorganic data supports the findings of the Phase I RI in that the majority of inorganic surface soil contamination is concentrated along the Track 49 embankment. The Phase I RI also indicated surface soil contamination in the T-Area and Former Burn Area; these areas were not sampled in the Phase II RI. No additional inorganic surface soil SRCs were identified in the Phase II samples. The Phase II data indicate that inorganic constituents above background criteria extend further north and south of the Track 49 embankment than previously indicated. With the exception of cadmium, metals were not present above the background criteria at the two stations in the southwestern portion of the T-Area (EBG-137 and -138) or in the northwest corner of EBG (EBG-140).

Station EBG-139, located in the northern culvert underlying Track 10, contained ten metals with concentrations above their background criteria. The maximum concentration for beryllium was detected in this sample (Table 4-4).

4.2.2.3 SVOCs, VOCs, and PCBs

A total of 64 SVOCs were analyzed for in ten surface soil samples collected at EBG during the Phase II RI (Table 4-2). Of these, 15 SVOCs were detected at least once. Table 4-5 lists the detected concentrations of these 15 SVOCs in surface soil.

Table 4-5. Phase II RI Site-related SVOCs in Surface Soil

Analyte (mg/kg)	Station						
	EBG-132	**EBG-133**	**EBG-134**	**EBG-135**	**EBG-136**	**EBG-137**	**EBG-139**
2-Methylnaphthalene				0.048 J		0.063 J	
Anthracene		0.077 J					
Benz(*a*)anthracene	0.13 J	0.36 J					
Benzo(*a*)pyrene	0.12 J	0.31 J		0.12 J			
Benzo(*b*)fluoranthene	0.31 J	0.76 =		0.26 J			0.2 J
Benzo(*g*,*h*,*i*)perylene	0.081 J	0.14 J	0.094 J	0.2 J	0.095 J		
Benzo(*k*)fluoranthene	0.098 J	0.22 J		0.099 J			
Bis(2-ethylhexyl)phthalate			0.079 J	0.78 =		0.49 =	0.16 J
Chrysene	0.16 J	0.45 =		0.15 J			0.12 J
Dibenz(*a*,*h*)anthracene		0.051 J					
Fluoranthene	0.099 J	0.27 J	0.081 J	0.082 J			0.14 J
Indeno(1,2,3-*cd*)pyrene	0.084 J	0.14 J		0.16 J			
Naphthalene			0.1 J			0.069 J	
Phenanthrene			0.12 J	0.1 J		0.054 J	
Pyrene	0.2 J	0.3 J					0.12 J

RI = Remedial investigation.
SVOC = Semivolatile organic compound.
* - value above facility-wide background criterion.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

SVOCs detected in the Phase II RI samples were similar to those observed in the Phase I RI: bis(2-ethylhexyl)phthalate and PAH compounds. Most Phase II results were low, estimated concentrations less than 1 mg/kg (Table 4-5 and Figure 4-3). Bis(2-ethylhexyl)phthalate was detected in Phase I RI samples

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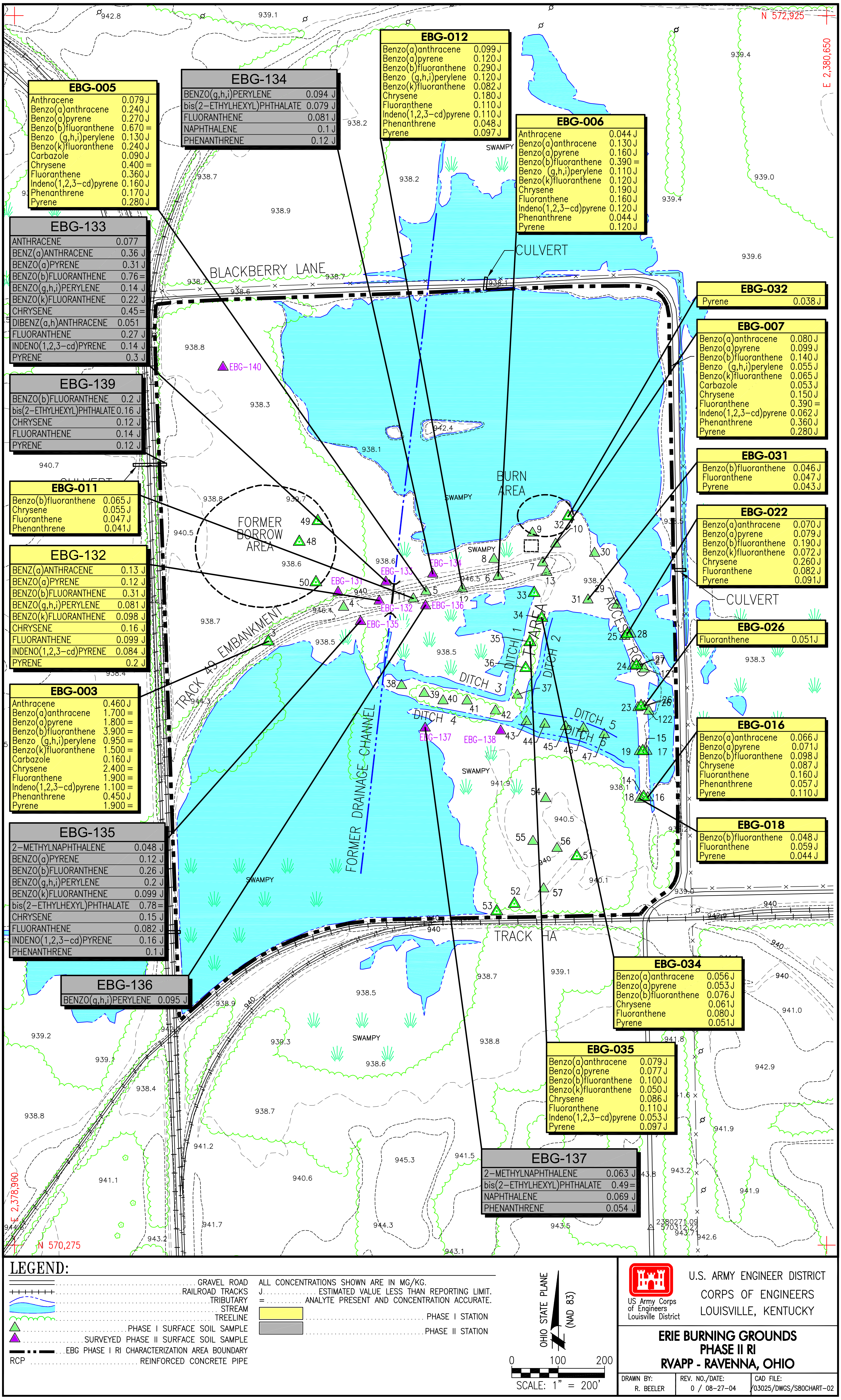


Figure 4-3. Distribution of SVOCs in Phase I and II Surface Soil

collected along the gravel access road and the wooded area south of the T-Area. Phase II data show this compound detected in the southern portion of the T-Area (EBG-137) and also in stations north and south of the Track 49 embankment (EBG-134 to the north and EBG-135 to the south), and in station EBG-139 in the north culvert underlying Track 10. The maximum concentration (0.78 mg/kg) was detected at EBG-135. The gravel access road was not sampled during the Phase II investigation.

PAH compounds were detected in the Phase I RI along the Track 49 embankment, the gravel access road, and the north leg of the T-Area. Phase II samples showed PAHs in all Track 49 locations except EBG-131, which is the most westerly location on the north side of the track. Maximum concentrations for PAH compounds mostly occurred at location EBG-133 on the north side of the Track 49 embankment (Table 4-5). Maximum concentrations for some compounds were detected at EBG-134, also on the north side of the track embankment, and EBG-135 on the south side of the embankment.

PAHs were also noted in Phase II RI samples collected at station EBG-137 (three PAH compounds). Four PAHs were detected in EBG-139 from the northern Track 10 culvert (Table 4-5).

Two surface soil samples were analyzed for VOCs. Toluene was detected in both samples at estimated concentrations of 0.0029J mg/kg in EBG-131, and 0.004J mg/kg in EBG-132. These stations are on the north and south sides of the Track 49 embankment, respectively. These samples were also analyzed for PCBs; however, no PCBs were detected.

4.2.3 Multi-increment Samples

Multi-increment surface soil samples were collected from five areas at EBG, as shown on Figure 3-1. These areas were: (1) the wooded area north of the Former Borrow Area, (2) the Former Borrow Area, (3) the north Track 49 embankment, (4) the south Track 49 embankment, and (5) the access road and northern T-Area. One multi-increment composite sample was collected from each of the five areas. Multi-increment samples were analyzed for explosives, TAL metals, cyanide, and SVOCs. Analytical results for the multi-increment samples are summarized in Table 4-6. The results for inorganic constituents have been compared to the facility-wide background concentrations for evaluation purposes.

4.2.3.1 Wooded area north of the Borrow Pit Area (EBG-141)

Explosives were not detected in this sample area. Cadmium and copper were the only inorganic constituents detected at concentrations exceeding facility-wide background concentrations. Benzoic acid at an estimated concentration of 0.22 J mg/kg was the only SVOC detected in this multi-increment sample (Table 4-6).

4.2.3.2 Borrow Pit Area (EBG-142)

Explosives were not detected in this sample area. Cadmium, copper, mercury, and thallium were the inorganic constituents detected at concentrations exceeding facility-wide background concentrations. Seven SVOCs were detected in this multi-increment sample (Table 4-6).

Table 4-6. Constituents Detected in Phase II RI Multi-increment Surface Soil Samples at Erie Burning Grounds

Analyte (mg/kg)	Station				
	EBG-141	**EBG-142**	**EBG-143**	**EBG-144**	**EBG-145**
Semivolatile Organics (mg/kg)					
2-Methylnaphthalene			0.039 J		
Benz(*a*)anthracene		0.059 J	0.19 J		0.072 J
Benzo(*a*)pyrene		0.046 J	0.19 J		
Benzo(*b*)fluoranthene		0.059 J	0.48 =		0.084 J
Benzo(*g*,*h*,*i*)perylene			0.15 J		
Benzo(*k*)fluoranthene			0.099 J		
Benzoic Acid	0.22 J				
Bis(2-ethylhexyl)phthalate			0.075 J		
Chrysene		0.053 J	0.24 J		0.059 J
Fluoranthene		0.15 J	0.23 J		0.11 J
Indeno(1,2,3-*cd*)pyrene			0.14 J		
Phenanthrene		0.09 J	0.064 J		
Pyrene		0.085 J	0.2 J		
Explosives (mg/kg)					
2,4,6-Trinitrotoluene			0.37 =		
2-Amino-4,6-dinitrotoluene			0.26 =		
4-Amino-2,6-dinitrotoluene			0.24 =		
Inorganics (mg/kg)					
Aluminum	8,310 =	8,180 =	13,500 =	12,900 =	7,350 =
Antimony	0.13 J	0.21 J	5.1 J *	4.6 J *	7.6 J *
Arsenic	4.3 =	3.3 =	9.8 =	9 =	6.9 =
Barium	41.2 =	52.9 =	186 = *	523 = *	80.6 =
Beryllium	0.31 =	0.33 =	0.82 =	0.38 =	0.54 =
Cadmium	0.12 J *	0.11 J *	1.2 = *	2.2 = *	0.71 = *
Chromium	10.2 =	9.9 =	24.2 = *	36.7 = *	20.1 = *
Cobalt	4.1 =	3.2 =	8.3 =	7.7 =	6 =
Copper	38.1 = *	17.9 = *	97.7 = *	196 = *	43.6 = *
Lead	16.5 =	16.2 =	101 = *	282 = *	112 = *
Manganese	109 J	81.6 J	676 J	596 J	450 J
Mercury	0.025 J	0.04 J *	0.21 J *	0.049 J *	0.046 J *
Nickel	8.6 =	8 =	20.9 =	26.2 = *	13.9 =
Silver			0.32 = *	3.8 = *	0.17 = *
Thallium		0.25 J *			
Vanadium	12.2 =	11.7 =	22.1 =	32.5 = *	12.1 =
Zinc	35.3 J	34.8 J	399 J *	991 J *	307 J *

RI = Remedial investigation.
SRC = Site-related contaminant.
* - value above facility-wide background criterion.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

4.2.3.3 North of the Track 49 Embankment (EBG-143)

The explosive compounds 2,4,6-TNT (0.37 mg/kg); 2-amino-4,6-DNT (0.26 mg/kg); and 4-amino-2,6-DNT (0.24 mg/kg) were detected in the multi-increment sample from this area.

Antimony, barium, cadmium, chromium, copper, lead, mercury, silver, and zinc were the inorganic constituents detected at concentrations exceeding facility-wide background concentrations. The highest reported concentration for barium (523 mg/kg) and mercury (0.21 J mg/kg) among the multi-increment samples was detected in this sample. Twelve SVOCs were also detected in this sample (Table 4-6).

4.2.3.4 South of the Track 49 Embankment (EBG-144)

Explosives were not detected in this sample area. Antimony, barium, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc were the inorganic constituents detected at concentrations exceeding facility-wide background concentrations in the multi-increment sample from south of the Track 49 embankment. The highest reported concentrations of barium (523 mg/kg), cadmium (2.2mg/kg), chromium (36.7 mg/kg), copper (196 mg/kg), lead (282 mg/kg), nickel (26.2 mg/kg), silver (3.8 mg/kg), vanadium (32.5 mg/kg), and zinc (991 mg/kg) among the EBG multi-increment samples were detected in this sample. No SVOCs were detected.

4.2.3.5 Access Road Area (EBG-145)

Explosives were not detected in this sample area. Antimony, cadmium, chromium, copper, lead, mercury, silver, and zinc were the inorganic constituents detected at concentrations exceeding facility-wide background concentrations in the multi-increment sample from the access road area. The highest antimony concentration (7.6 J mg/kg) reported for the multi-increment samples was detected in this sample. Four SVOCs were also detected (Table 4-6).

4.2.4 Summary

Explosives and Propellants

The results of the Phase II RI identified four new site-related explosive compounds in addition to 2,4,6-TNT (2,6-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and RDX). The Phase I RI compounds 4-nitrotoluene; 1,3,5-TNB; and 2,4-DNT were not detected during the Phase II RI. The occurrence of explosives and propellants during the Phase II RI is similar to the occurrence determined during the Phase I RI, with these compounds being found mainly along the north and south embankment of Track 49. This is primarily true of the compound 2,4,6-TNT, which was detected along the embankment during the Phase I and Phase II RIs.

Inorganic Constituents

A total of 18 inorganics were identified as SRCs in Phase II surface soil samples. The Phase II RI results for inorganics were similar to the Phase I results with aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc detected at all sampling locations. Sample locations on the north and south sides of the Track 49 embankment had the highest number of constituents exceeding background concentrations. Station EBG-139, located in the north culvert underlying Track 10, also had a high number (ten) of inorganic SRCs exceeding background criteria, including the maximum concentration for beryllium.

SVOCs, VOCs, and PCBs

During the Phase II RI, surface soil samples located on the north and south sides of the Track 49 embankment had the highest number of compounds and the highest concentrations of SVOCs. As was found during the Phase I RI, bis(2-ethylhexyl)phthalate and PAHs were the most prevalent SVOCs in surface soils. The MDCs of most of the compounds detected during the Phase II RI occur along the Track 49 embankment. Toluene was the only VOC detected in surface soils during the Phase II RI and this compound occurred at low estimated concentrations at two stations in the Track 49 embankment area.

PCB compounds were not detected in any of the Phase I or Phase II RI surface soil samples.

Multi-increment samples

Explosives were detected in the multi-increment sample EBG-143 from the north Track 49 embankment area. The compounds detected include 2,4,6-TNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT.

Inorganic constituents were detected at all multi-increment sample locations. The number of constituents that exceeded background concentrations ranged from 2 to 14, with sample EBG-144 containing 11 SRCs exceeding background and EBG-143 containing 9 above background.

At least one SVOC was detected in 4 of the 5 multi-increment samples, and as many as 12 SVOCs were detected. No SVOCs were detected in EBG-144 to the south of Track 49 embankment. The greatest number of compounds was reported for the multi-increment sample EBG-143 from the north Track 49 embankment. Sample EBG-142, located in the vicinity of the Former Borrow Area, also contained seven SVOCs.

4.3 SUBSURFACE SOILS

The Phase II RI investigation at EBG did not include sampling of subsurface soil for chemical analysis. Shelby tube samples of subsurface soils were collected from five of the eight new groundwater monitoring wells installed at EBG for geotechnical analysis only. A summary of the geotechnical results is presented in Section 4.3.2.

4.3.1 Summary of Phase I Remedial Investigation Data

The following provides a summary of the key findings of the results of the Phase I RI with respect to subsurface soils at EBG. Additional information on SRCs identified in subsurface soil is presented in Section 1.3.3.

- Explosives in subsurface soil occur mainly along the Track 49 embankment and gravel access road. The distribution of explosives was much less extensive in subsurface soil than in surface soil. The most frequently detected explosive was 2,4,6-TNT. Other explosives were detected in one or two samples. The propellant nitrocellulose was detected once.

- Inorganics are pervasive in subsurface soil. Aluminum, arsenic, barium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc were detected in 100% of the subsurface soil samples. As with surface soil, the Track 49 embankment, gravel access road, and T-Area were the primary areas of metals contamination. Concentrations above background are lower in subsurface soil than in surface soil.

- SVOC contamination consists of bis(2-ethylhexyl)phthalate on the gravel access road, the wooded area south of the T-Area, and along Track 49 embankment. PAH compounds were detected at three stations on the Track 49 embankment and at one station on the gravel access road. VOCs (acetone, toluene, and methylene chloride) were sporadically detected. No PCB compounds were detected.

The complete results of the Phase I RI at EBG can be found in the report for that investigation (USACE 2001c) and are not presented further in this report.

4.3.2 Geotechnical Results

Six Shelby tubes were collected from five monitoring well locations [EBGmw-124, -125, -128 (two depth intervals), -129, and -130]. These samples were submitted for grain size distribution analyses, Atterburg limits analyses, bulk density, moisture content, specific gravity, and USCS classification. Table 4-7 provides a summary of the geotechnical data for subsurface soil at EBG.

Sieve analyses and USCS classification identified the samples as ranging from clay to silty, clayey sands with gravel. Moisture content of the samples varied depending on the location, with results ranging from 13.7% [5.5 to 6.1 m (18 to 20 ft) bgs at EBGmw-124] to 24.5% [6.7 to 7.3 m (22 to 24 ft) bgs at EBGmw-128].

Four of the six samples selected for Atterberg limits analyses were identified as having some degree of plasticity, with the samples from EBGmw-125 and -129 being classified non-plastic. Specific gravity ranged from 2.64 to 2.72, and porosity ranged from .255 to .394 cm^3/cm^3 (Table 4-7). Adequate material was not available in the sample from EBGmw-129 to perform the bulk density for the porosity test, and, therefore, the specific gravity analysis was also not performed. The complete geotechnical report is included in Appendix I of this RI report.

4.4 SEDIMENT

4.4.1 Summary of Phase I Remedial Investigation Data

The following summarizes the key nature and extent findings of the results for sediment samples collected during the Phase I RI.

- Explosives were detected primarily in sediment samples from the access road and staging/parking area, Track 49 embankment, Former Burn Area, and the north surface water basin. Nitrobenzene was detected at the EBG outlet location, but explosives were not detected at station EBG-120, located a short distance downstream of the outlet. With the exception of the two stations closest to the Track 49 embankment, explosives were not detected in T-Area sediments or in any of the remaining surface water basins. Explosives also were not detected at any of the off-AOC locations sampled downstream along the EBG exit drainage (EBG-114, -116, and -117, and PF534).

- Metals above background occur in sediment throughout the site, but primarily in the T-Area (north and eastern legs), the Former Burn Area, the north and east basins, and the north and east inlets. The western leg of the T-Area, the west and south surface water basins, and the EBG outlet show minimal inorganic concentrations above background. Metals above background were not detected at station EBG-120, just downstream of the EBG outlet.

Table 4-7. Geotechnical Data for Erie Burning Grounds Phase II RI Monitoring Well Borings

Sample ID	Station Number	Depth (ft)	Water Content (%)	Grain Size Analysis				Atterberg Limits			Porosity (cm^3/cm^3)	Specific Gravity	Wet Density (lb/ft^3)	Dry Density (lb/ft^3)	USCS Classification
				Gravel	**Sand**	**Silt**	**Clay**	**LL**	**PL**	**PI**					
EBG-284	EBGmw-124	18-20	13.7	7.6	53.5	24.1	14.8	16	10	6	.225	2.65	140.1	123.2	Silty clayey sand with gravel, SC-SM
EBG-285	EBGmw-125	22-24	17.5	0.1	92.1	4.4	3.4	NP	NP	NP	.346	2.64	126.3	107.5	Poorly graded sand with silt, SP-SM
EBG-288	EBGmw-128	16-18	20.9	0.0	2.7	61.6	35.7	26	15	11	.353	2.72	132.8	109.9	Lean clay with sand, CL
EBG-288	EBGmw-128	22-24	24.5	0.0	11.6	80.6	7.8	23	17	6	.394	2.71	127.7	102.6	Sandy, clayey silt, CL-ML
EBG-289	EBGmw-129	20-22	TNP	1.9	86.7	8.8	2.6	NP	NP	NP	TNP	TNP	TNP	TNP	Well graded sand with silt, SW-SM
EBG-290	EBGmw-130	24-24.7	16.4	2.8	28.8	40.9	27.5	24	13	11	.266	16.4	142.8	122.7	Lean clay with sand, CL

ID = Identifier.
TNP = Test not performed.
NP = Non plastic.
RI = Remedial investigation.
USCS = Unified Soil Classification System.

- SVOCs [PAHs and bis(2ethylhexyl)phthalate] were detected in sediment along the Track 49 embankment and the Former Burn Area. SVOCs were not detected in any of the off-AOC sediment locations.

4.4.2 Discrete Samples

Sediment samples were collected from seven locations during the Phase II RI to assess the potential for contaminant migration via erosion to surface water and sediment, to evaluate the potential contaminant accumulation areas to determine if residual contamination exists and if these areas could act as secondary sources for contamination, and to evaluate potential contaminant exit pathways from EBG. As discussed in Section 4.1, EBG-139 was included in the surface soil aggregate as it was collected from a drainage conveyance that is dry for the majority of the year. The remaining six sediment samples are discussed below. Table 4-8 provides summary statistics and SRCs identified from the screening of the Phase II RI data.

4.4.2.1 Explosives and propellants

Low concentrations of two explosives were detected in EBG sediment samples collected during the Phase II RI. Nitrobenzene was detected at an estimated concentration of 0.091 J mg/kg at EBG-146 and HMX was detected at a concentration of 0.19 mg/kg at EBG-148. Station EBG-146 is located at the north inlet (culvert beneath Blackberry Lane) on the northern boundary of EBG and station EBG-148 is located in the former drainage channel in the southwestern portion of EBG.

Explosives had not been detected previously in the south surface water drainage basin; however, sample EBG-148 was collected from within the former drainage channel connecting the north and south basins, and may indicate accumulation of contamination due to runoff from the Track 49 embankment or T-Area. The Phase I RI indicated that the north basin did have notable sediment contamination. The occurrence of trace levels of nitrobenzene at the north inlet (EBG-146) may be due to simple dispersal of contaminated sediment throughout the north basin during storm or high water events. Explosives were not detected at the EBG outlet location (EBG-149) or downstream locations (EBG-150 and -151), indicating that migration of explosive-contaminated sediment out of the AOC is minimal. To provide a representative illustration of the nature and extent for this class of contaminants, the distribution and concentrations of explosives and propellants are provided on Figure 4-4.

4.4.2.2 Inorganic constituents

A total of 22 metals were detected at least once in sediment during the Phase II RI (Table 4-8). Nine of the detected metals were eliminated as potential SRCs because they were either major geochemical constituents normally considered as essential elements (calcium, iron, potassium, magnesium, and sodium) or did not exceed the facility-wide background concentrations (arsenic, cobalt, manganese, and thallium). Cyanide was not detected in any of the Phase II RI sediment samples. Table 4-9 contains the results for the 13 inorganic SRCs in sediment samples collected during the Phase II RI.

For those metals retained as SRCs, antimony, beryllium, cadmium, and silver were detected above background in at least five of six Phase II sediment samples, and were identified as pervasive across the site. Antimony, cadmium, and silver were not detected in the background data set, so the background criteria were set to zero for these constituents. To provide a representative illustration of the nature and extent for this class of contaminants, the distribution and concentrations of selected principal metals constituents are provided on Figure 4-5. The illustrations include a designation of the concentrations exceeding background at a given station.

Table 4-8. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Grounds Sediment

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL$_{95}$ of Mean	Exposure Concentration	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Explosives											
HMX	2691-41-0	mg/kg	1/ 6	1.15E-01	1.90E-01	1.90E-01	1.45E-01	1.45E-01	0	Yes	Yes
Nitrobenzene	98-95-3	mg/kg	1/ 6	5.68E-02	9.10E-02	9.10E-02	7.06E-02	7.06E-02	0	Yes	Yes
Metals											
Aluminum	7429-90-5	mg/kg	6/ 6	1.16E+04	8.11E+03	2.10E+04	1.68E+04	1.68E+04	1.39E+04	Yes	Yes
Antimony	7440-36-0	mg/kg	5/ 6	3.98E-01	2.30E-01	1.00E+00	2.71E+00	1.00E+00	0	Yes	Yes
Arsenic	7440-38-2	mg/kg	6/ 6	7.60E+00	6.60E+00	9.40E+00	8.49E+00	8.49E+00	1.95E+01	No	No
Barium	7440-39-3	mg/kg	6/ 6	1.24E+02	7.16E+01	2.60E+02	2.11E+02	2.11E+02	1.23E+02	Yes	Yes
Beryllium	7440-41-7	mg/kg	6/ 6	5.62E-01	3.80E-01	7.60E-01	6.68E-01	6.68E-01	3.80E-01	Yes	Yes
Cadmium	7440-43-9	mg/kg	6/ 6	8.62E-01	5.40E-01	1.10E+00	1.05E+00	1.05E+00	0	Yes	Yes
Calcium	7440-70-2	mg/kg	6/ 6	3.86E+03	2.52E+03	5.53E+03	5.40E+03	5.40E+03	5.51E+03	Yes	No
Chromium	7440-47-3	mg/kg	6/ 6	1.59E+01	1.02E+01	2.43E+01	2.14E+01	2.14E+01	1.81E+01	Yes	Yes
Cobalt	7440-48-4	mg/kg	6/ 6	5.37E+00	4.20E+00	7.20E+00	6.47E+00	6.47E+00	9.10E+00	No	No
Copper	7440-50-8	mg/kg	6/ 6	2.94E+01	1.52E+01	5.55E+01	5.16E+01	5.16E+01	2.76E+01	Yes	Yes
Iron	7439-89-6	mg/kg	6/ 6	1.71E+04	1.30E+04	2.14E+04	2.03E+04	2.03E+04	2.82E+04	No	No
Lead	7439-92-1	mg/kg	6/ 6	2.33E+01	1.54E+01	3.60E+01	3.27E+01	3.27E+01	2.74E+01	Yes	Yes
Magnesium	7439-95-4	mg/kg	6/ 6	2.98E+03	1.55E+03	7.30E+03	6.20E+03	6.20E+03	2.76E+03	Yes	No
Manganese	7439-96-5	mg/kg	6/ 6	1.92E+02	1.29E+02	2.62E+02	2.43E+02	2.43E+02	1.95E+03	No	No
Mercury	7487-94-6	mg/kg	6/ 6	4.82E-02	2.90E-02	7.50E-02	7.28E-02	7.28E-02	5.90E-02	Yes	Yes
Nickel	7440-02-0	mg/kg	6/ 6	1.49E+01	1.03E+01	1.81E+01	1.72E+01	1.72E+01	1.77E+01	Yes	Yes
Potassium	7440-09-7	mg/kg	6/ 6	1.08E+03	8.27E+02	1.26E+03	1.24E+03	1.24E+03	1.95E+03	No	No
Silver	7440-22-4	mg/kg	6/ 6	1.07E-01	6.40E-02	1.80E-01	1.78E-01	1.78E-01	0	Yes	Yes
Sodium	7440-23-5	mg/kg	6/ 6	7.37E+01	4.17E+01	1.25E+02	1.20E+02	1.20E+02	1.12E+02	Yes	No
Thallium	6533-73-9	mg/kg	2/ 6	2.61E-01	4.70E-01	6.60E-01	4.61E-01	4.61E-01	8.90E-01	No	No
Vanadium	7440-62-2	mg/kg	6/ 6	1.92E+01	1.36E+01	2.79E+01	2.44E+01	2.44E+01	2.61E+01	Yes	Yes
Zinc	7440-66-6	mg/kg	6/ 6	2.20E+02	9.00E+01	8.15E+02	4.60E+02	4.60E+02	5.32E+02	Yes	Yes
Miscellaneous											
Total Organic Carbon	N997	%	6/ 6	4.08E-01	3.30E-01	5.70E-01	5.09E-01	5.09E-01	NA	NA	NA

Table 4-8. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Grounds Sediment (continued)

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL_{95} of Mean	Exposure Concentration	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Organics-Pesticide/PCB											
Methoxychlor	72-43-5	mg/kg	1/ 6	2.67E-03	7.30E-03	7.30E-03	4.55E-03	4.55E-03	0	Yes	Yes
Organics-Semivolatile											
Bis(2-ethylhexyl)phthalate	117-81-7	mg/kg	5/ 6	2.59E-01	1.00E-01	4.60E-01	3.74E-01	3.74E-01	0	Yes	Yes
Fluoranthene	206-44-0	mg/kg	1/ 6	3.06E-01	8.20E-02	8.20E-02	4.10E-01	8.20E-02	0	Yes	Yes
Organics-Volatile											
2-Butanone	78-93-3	mg/kg	3/ 6	1.26E-02	1.10E-02	1.30E-02	1.89E-02	1.30E-02	0	Yes	Yes
Toluene	108-88-3	mg/kg	1/ 6	4.76E-03	2.30E-03	2.30E-03	6.01E-03	2.30E-03	0	Yes	Yes

[a] One-half of the detection limit was used as a surrogate value for nondetects in the calculation of summary statistics.
[b] Background criteria were set to zero for all organics and inorganics that were not detected in the background dataset.
[c] The essential nutrient screen was not applied for the ecological risk assessment.
CAS = Chemical Abstracts Service.
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.
NA = Not applicable.
PCB = Polychlorinated biphenyl.
RI = Remedial investigation.
SRC = Site-related contaminant.

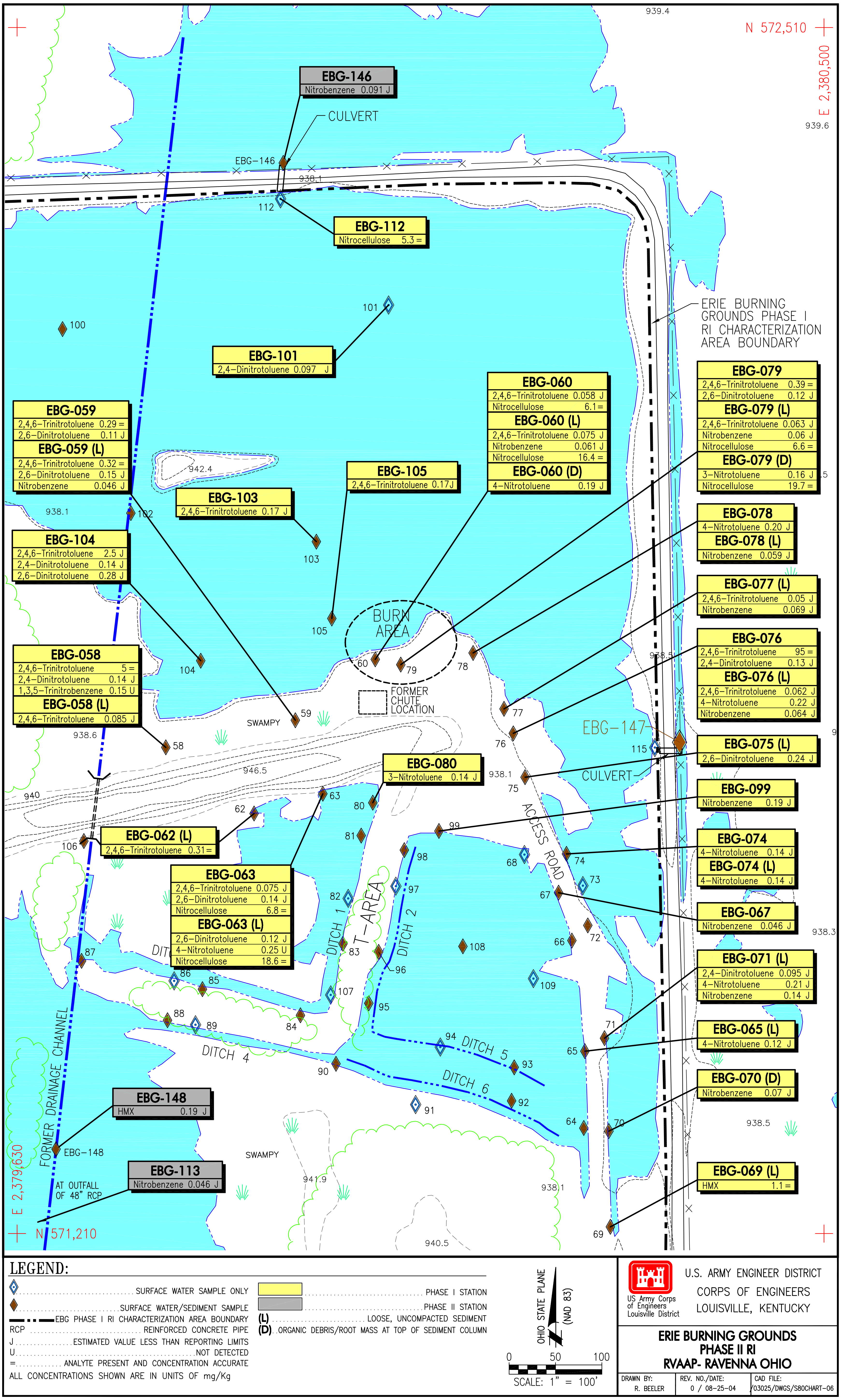


Figure 4-4. Distribution of Explosives and Propellants in EBG Phase I and II Sediment Samples

Table 4-9. Phase II RI Inorganic SRCs Detected in Sediment at Erie Burning Grounds

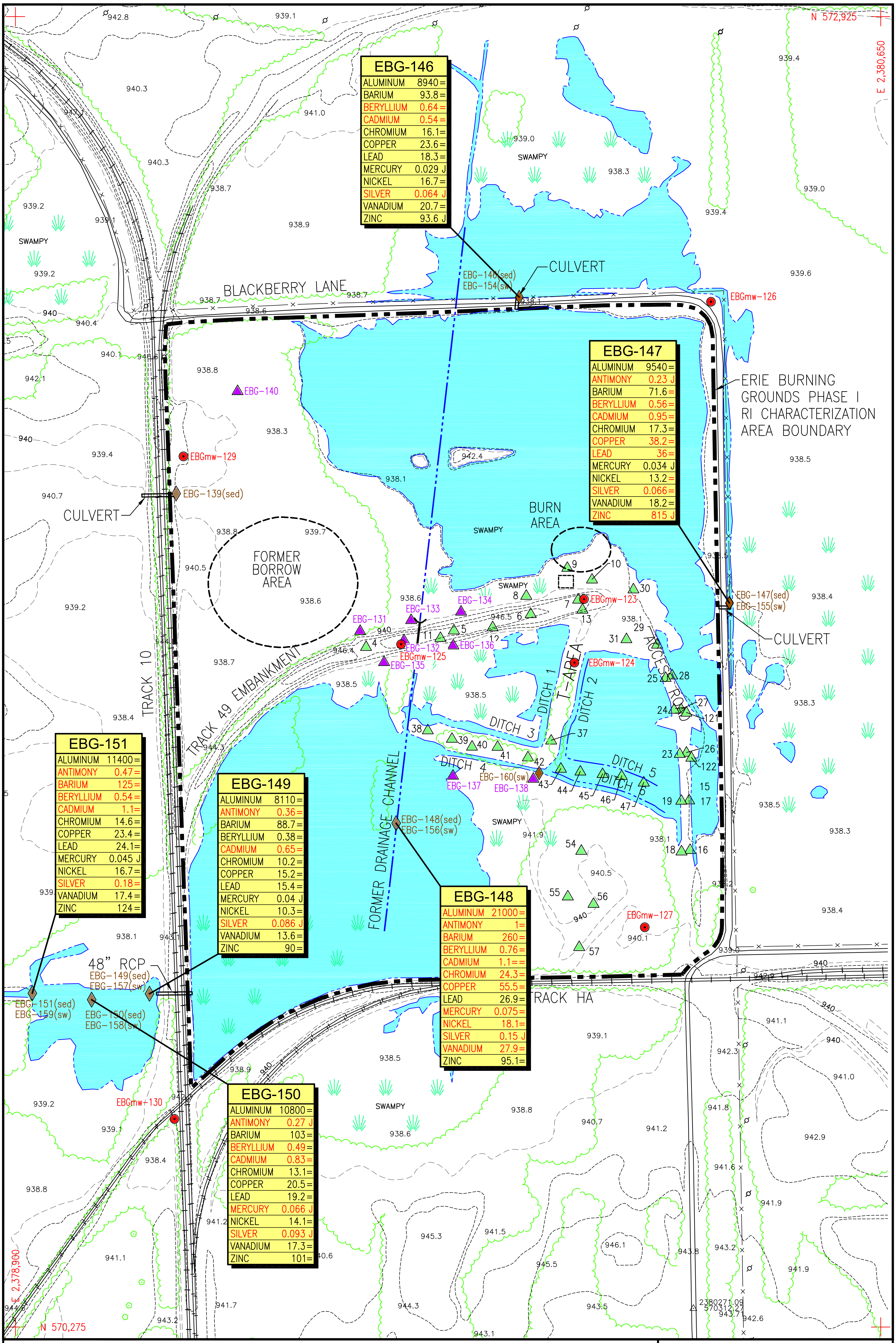
Analyte (mg/kg)	Station					
	EBG-146 North Inlet	**EBG-147 East Inlet**	**EBG-148 Former Drainage Channel**	**EBG-149 EBG Outlet**	**EBG-150 Downstream of EBG Outlet**	**EBG-151 Downstream of EBG Outlet**
Aluminum	8,940 =	9,540 =	21,000 = *	8,110 =	10,800 =	11,400 =
Antimony		0.23 J *	1 = *	0.36 = *	0.27 J *	0.47 = *
Barium	93.8 =	71.6 =	260 = *	88.7 =	103 =	125 = *
Beryllium	0.64 = *	0.56 = *	0.76 = *	0.38 =	0.49 = *	0.54 = *
Cadmium	0.54 = *	0.95 = *	1.1 = *	0.65 = *	0.83 = *	1.1 = *
Chromium	16.1 =	17.3 =	24.3 = *	10.2 =	13.1 =	14.6 =
Copper	23.6 =	38.2 = *	55.5 = *	15.2 =	20.5 =	23.4 =
Lead	18.3 =	36 = *	26.9 =	15.4 =	19.2 =	24.1 =
Mercury	0.029 J	0.034 J	0.075 = *	0.04 J	0.066 J *	0.045 J
Nickel	16.7 =	13.2 =	18.1 = *	10.3 =	14.1 =	16.7 =
Silver	0.064 J *	0.066 J *	0.15 J *	0.086 J *	0.093 J *	0.18 = *
Vanadium	20.7 =	18.2 =	27.9 = *	13.6 =	17.3 =	17.4 =
Zinc	93.6 J	815 J *	95.1 =	90 =	101 =	124 =

EBG = Erie Burning Grounds.
RI = Remedial investigation.
J - estimated concentration.
= - accurate concentration.
* - concentration exceeds facility-wide background.
Blank cells indicate constituent was not detected.

In general, the greatest occurrence of metals above background values occurred in sample EBG-148, collected from the former drainage channel in the southwestern portion of EBG. The elevated concentrations of metals in these areas likely reflect the accumulation of constituents due to runoff from the Track 49 embankment area. Samples from the pond at the southwest EBG outlet contained as many as five metals above background. Antimony, beryllium, cadmium, and silver were detected above background in at least two of the three samples collected from this area.

As with surface soil, various inorganics were present in sediment above background criteria across the entire EBG site. Beryllium, not a SRC in the Phase I RI, was detected above background values in five of six sediment samples collected during the Phase II RI, but the MDC was less than twice the background criteria. In the Phase I RI, metals above background were not detected at the EBG outlet. Phase II data indicate that between three and five metals are present downstream of the outlet at concentrations exceeding background criteria; however, three of these (antimony, cadmium, and silver) have background criteria of zero.

The Phase II sample collected from the vicinity of the former drainage channel bisecting the south basin contained the highest number of inorganic SRCs above background. As was the case for explosives, this drainage channel represents a potential site of accumulation of contamination from runoff from the



EBG-146

ALUMINUM	8940=
BARIUM	93.8=
BERYLLIUM	0.64=
CADMIUM	0.54=
CHROMIUM	16.1=
COPPER	23.6=
LEAD	18.3=
MERCURY	0.029 J
NICKEL	16.7=
SILVER	0.064 J
VANADIUM	20.7=
ZINC	93.6 J

EBG-147

ALUMINUM	9540=
ANTIMONY	0.23 J
BARIUM	71.6=
BERYLLIUM	0.56=
CADMIUM	0.95=
CHROMIUM	17.3=
COPPER	38.2=
LEAD	36=
MERCURY	0.034 J
NICKEL	13.2=
SILVER	0.066=
VANADIUM	18.2=
ZINC	815 J

EBG-151

ALUMINUM	11400=
ANTIMONY	0.47=
BARIUM	125=
BERYLLIUM	0.54=
CADMIUM	1.1=
CHROMIUM	14.6=
COPPER	23.4=
LEAD	24.1=
MERCURY	0.045 J
NICKEL	16.7=
SILVER	0.18=
VANADIUM	17.4=
ZINC	124=

EBG-149

ALUMINUM	8110=
ANTIMONY	0.36=
BARIUM	88.7=
BERYLLIUM	0.38=
CADMIUM	0.65=
CHROMIUM	10.2=
COPPER	15.2=
LEAD	15.4=
MERCURY	0.04 J
NICKEL	10.3=
SILVER	0.086 J
VANADIUM	13.6=
ZINC	90=

EBG-148

ALUMINUM	21000=
ANTIMONY	1=
BARIUM	260=
BERYLLIUM	0.76=
CADMIUM	1.1==
CHROMIUM	24.3=
COPPER	55.5=
LEAD	26.9=
MERCURY	0.075=
NICKEL	18.1=
SILVER	0.15 J
VANADIUM	27.9=
ZINC	95.1=

EBG-150

ALUMINUM	10800=
ANTIMONY	0.27 J
BARIUM	103=
BERYLLIUM	0.49=
CADMIUM	0.83=
CHROMIUM	13.1=
COPPER	20.5=
LEAD	19.2=
MERCURY	0.066 J
NICKEL	14.1=
SILVER	0.093 J
VANADIUM	17.3=
ZINC	101=

LEGEND:

═	GRAVEL ROAD
┼┼┼┼	RAILROAD TRACKS
∼	TRIBUTARY
∼	STREAM
∼	TREELINE
△	PHASE I SURFACE & SUBSURFACE SOIL SAMPLE
▲	SURVEYED PHASE II SURFACE SOIL SAMPLE
◆	SURVEYED PHASE II SEDIMENT/SURFACE WATER SAMPLE
●	SURVEYED PHASE II MONITORING WELL
— · · —	EBG PHASE I RI CHARACTERIZATION AREA BOUNDARY
RCP	REINFORCED CONCRETE PIPE

ALL CONCENTRATIONS SHOWN ARE IN MG/KG.
682 ..... EXCEEDS FACILITY-WIDE BACKGROUND CONCENTRATION
J ..... ESTIMATED VALUE LESS THAN REPORTING LIMIT.
= ..... ANALYTE PRESENT AND CONCENTRATION ACCURATE.

OHIO STATE PLANE (NAD 83)

0 100 200
SCALE: 1" = 200'

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

US Army Corps of Engineers
Louisville District

ERIE BURNING GROUNDS
PHASE II RI
RVAPP - RAVENNA, OHIO

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	0 / 08-27-04	/03025/DWGS/S80-CHRT06

Figure 4-5. Occurrence of Inorganics in Sediment, EBG Phase II RI

Track 49 embankment or the T-Area. The sediment samples from the north and east inlets contained between three and seven inorganic SRCs above background, respectively, and may represent contaminant flux into EBG from upstream areas, or, more likely, runoff from the gravel roadbed and deterioration of the galvanized culverts at these locations.

4.4.2.3 SVOCs, VOCs, and PCBs

All six sediment samples were analyzed for SVOCs, VOCs, and pesticides/PCBs. Bis(2-ethylhexyl)phthalate was detected in five of six samples, and fluoranthene was detected in one sample (EBG-151) located downstream of the EBG outlet (Figure 4-6). The MDC (0.46 mg/kg) of bis(2-ethylhexyl)phthalate occurred at the EBG outlet station EBG-149. PAHs and bis(2-ethylhexyl)phthalate were detected in the Phase I samples along Track 49 embankment and the Former Burn Area. SVOCs were not detected in Phase I samples in any of the surface water basins, or at off-site locations. The Phase II data indicate that low levels of SVOCs may be more widespread than previously believed, although migration out of the AOC, as evidenced by few detections of these compounds in the three sediment samples, directly downstream of the EBG outlet is minimal.

The VOC 2-butanone was detected at three locations (EBG-148, -149, and -151) in the south basin, EBG outlet, and downstream of the EBG outlet. Toluene was detected at station EBG-151. Both of these compounds were detected during the Phase I RI; 2-butanone in over half the Phase I samples with no apparent pattern of distribution, and toluene concentrated along the Track 49 embankment.

Phase II data indicated the presence of methoxychlor at a concentration of 0.0073J mg/kg at EBG-148. This pesticide was not detected in the Phase I samples and represents an additional SRC identified during the Phase II RI. PCBs, detected in the Phase I RI (PCB-1254 in the Former Burn Area), were not detected in Phase II RI samples.

4.4.3 Multi-increment Samples

Multi-increment sediment samples were collected from two areas within the EBG boundary. These samples were collected from the north (EBG-153) and south (EBG-152) basins and represent average sediment concentrations for these two areas. Three multi-increment samples were obtained from each of the two areas. The multi-increment samples were analyzed for explosives, TAL metals, SVOCs, and pesticides/PCBs. The results for the constituents detected in the multi-increment sediment samples are included in Table 4-10. The locations of the multi-increment sample areas are indicated in Figure 3-1.

4.4.3.1 South Basin (EBG-152)

Three multi-increment samples were collected from the vicinity of the former drainage channel in the south basin. Explosive compounds were detected at low levels in only one of the three multi-increment sediment samples (2,4,6-TNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitroglycerin).

Inorganic constituents were detected at all multi-increment sample locations from the south basin. The number of inorganic constituents that exceeded background concentrations ranged from 11 to 13, and included aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, copper, lead, mercury, nickel, silver, and zinc. Of these constituents, antimony, barium, beryllium, cadmium, chromium, copper, lead, mercury, and silver were most frequently observed above background. Concentrations were similar among the three samples, although sample EBGsd-152-0314-SD exhibited slightly higher values for most constituents.

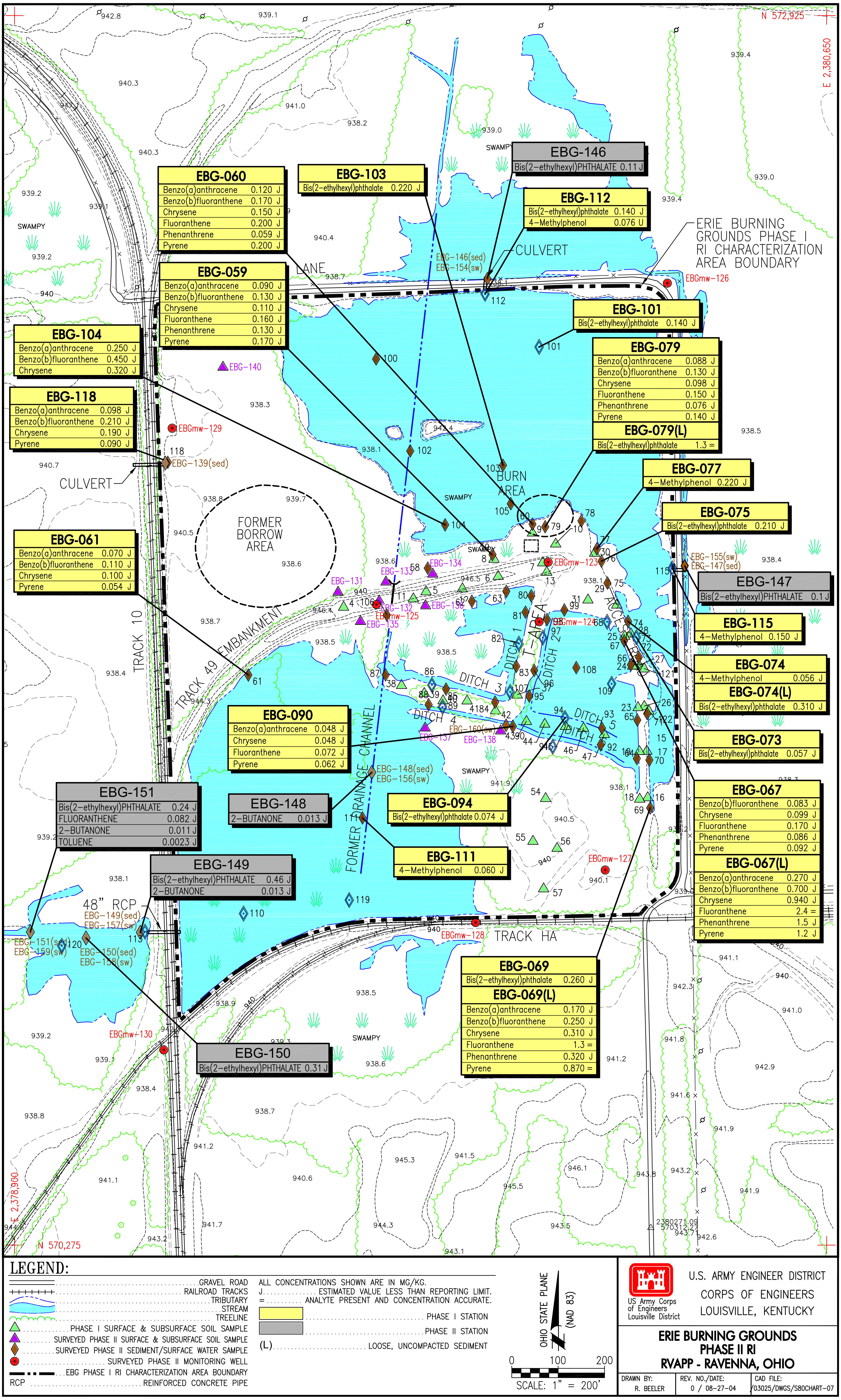


Figure 4-6. Occurrence of SVOCs and VOCs in Sediment, EBG Phase I and II RI

Table 4-10. Constituents Detected in Phase II RI Multi-increment Sediment Samples at Erie Burning Grounds

Analyte	South Basin (EBG-152)			North Basin (EBG-153)		
	EBGsd-152-0312-SD	**EBGsd-152-0313-SD**	**EBGsd-152-0314-SD**	**EBGsd-153-0315-SD**	**EBGsd-153-0316-SD**	**EBGsd-153-0317-SD**
SVOCs (mg/kg)						
2,4-Dinitrotoluene				0.21 J	0.3 J	0.12 J
2-Methylnaphthalene	0.11 J	0.091 J	0.12 J			
Benz(*a*)anthracene				0.13 J	0.1 J	0.13 J
Benzo(*a*)pyrene				0.17 J	0.14 J	0.14 J
Benzo(*b*)fluoranthene				0.27 J	0.24 J	0.25 J
Benzo(*g*,*h*,*i*)perylene				0.15 J	0.14 J	0.13 J
Bis(2-ethylhexyl)phthalate			0.096 J			
Chrysene				0.17 J	0.13 J	0.17 J
Di-n-butyl phthalate				0.29 J		
Fluoranthene	0.15 J	0.12 J	0.18 J	0.25 J	0.19 J	0.19 J
Indeno(1,2,3-*cd*)pyrene				0.13 J	0.12 J	0.11 J
Phenanthrene	0.19 J	0.17 J	0.21 J	0.11 J	0.11 J	0.099 J
Pyrene				0.21 J	0.18 J	0.17 J
Pesticides and PCBs (mg/kg)						
4,4'-DDE						0.0018 J
Endrin						0.0072 J
Explosives (mg/kg)						
2,4,6-Trinitrotoluene			0.93 =	16 =	21 =	3.4 =
2,4-Dinitrotoluene				0.19 =	0.17 =	0.15 =
2-Amino-4,6-dinitrotoluene			0.2 =	4.4 =	8.3 =	7.7 =
4-Amino-2,6-dinitrotoluene			0.054 J	15 =	3.2 =	3.1 =
Nitroglycerin			40 J		20 J	29 J
Inorganics (mg/kg)						
Aluminum	12,600 =	13,400 =	14,500 = *	13,400 =	16,300 = *	14,500 = *
Antimony	1.2 J *	0.89 J *	1.2 J *	69.4 J *	92.2 J *	97.2 J *
Barium	178 = *	191 = *	215 = *	277 = *	375 = *	383 = *
Beryllium	0.68 = *	0.67 = *	0.82 = *	0.9 = *	1 = *	1.1 = *
Cadmium	1.1 = *	1.1 = *	1.3 = *	2.7 = *	4.4 = *	4.9 = *
Chromium	18.4 = *	19.6 = *	21.3 = *	39.6 = *	49.4 = *	46.4 = *
Copper	66.9 = *	88.1 = *	103 = *	603 = *	305 = *	399 = *
Lead	30.6 = *	30.4 = *	38.3 = *	330 = *	373 = *	401 = *
Mercury	0.071 = *	0.078 = *	0.081 = *	0.21 J *	0.31 J *	0.31 J *
Nickel	16 =	16.1 =	18.1 = *	52.8 = *	27.1 = *	32.4 = *
Silver	0.16 J *	0.2 = *	0.22 J *	1.1 = *	1.2 = *	1.3 = *
Vanadium	21.4 =	21.2 =	23.6 =	20.1 =	25 =	22.1 =
Zinc	114 J	134 J	161 J	944 J *	1,280 J *	1,370 J *

DDE = Dichlorodiphenyldichloroethene.
PCB = Polychlorinated biphenyl.
RI = Remedial investigation.
SRC = Site-related contaminant.
* - value above facility-wide background criterion.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

SVOCs detected in the multi-increment samples from the south basin include 2-methylnaphthalene, bis(2-ethylhexyl)phthalate, fluoranthene, and phenanthrene.

Pesticides and PCBs were not detected in multi-increment samples from the south basin.

4.4.3.2 North Basin (EBG-153)

Three multi-increment samples were collected from the north basin. Explosive compounds were detected in all three of the multi-increment sediment samples. The compounds 2,4,6-TNT; 2,4-DNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitroglycerin were detected at similar concentrations.

Inorganic constituents were detected at all multi-increment sample locations from the north basin. The number of inorganic constituents that exceeded background concentrations ranged from 13 to 15, and included aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, copper, lead, magnesium, mercury, nickel, silver, sodium, and zinc. Of these constituents, antimony, barium, beryllium, cadmium, calcium chromium, copper, lead, mercury, nickel, silver, sodium, and zinc were most frequently observed above background.

As many as 11 SVOCs were detected in the multi-increment sediment samples. These include 2,4-DNT; benz(*a*)anthracene; benzo(*a*)pyrene; benzo(*b*)fluoranthene; benzo(*g,h,i*)perylene; chrysene; di-n-butyl phthalate; fluoranthene; indeno(1,2,3-*cd*)pyrene; phenanthrene; and pyrene.

The pesticides 4,4'-dichlorodiphenyldichloroethene (DDE) (0.0018 mg/kg) and endrin (0.0072 mg/kg) were detected at trace levels in one of the three north basin multi-increment sediment samples.

4.4.4 Summary

- Phase II RI sediment samples illustrate the presence of only trace levels of explosives at the north inlet (nitrobenzene) and in the former drainage channel in the south basin (HMX). Explosives had not been previously detected in the south surface water drainage basin. Explosives or propellants were not detected in Phase II sediment samples downstream of the EBG outlet.

- Inorganics exceeding background concentrations were detected primarily in the former drainage channel in the south basin, as well as in sediment stations located at the north and east inlets, and downstream of the EBG outlet. Inorganics were not detected above background at the EBG outlet in the Phase I RI. Beryllium was detected above background in five of six Phase II sediment samples; this metal was not identified as a SRC in the Phase I RI.

- Few SVOCs were detected in Phase II RI sediment samples. Bis(2-ethylhexyl)phthalate was detected in five of six sediment samples, fluoranthene occurred at only one station downstream of the EBG outlet. Few VOCs were also detected. The pesticide methoxychlor, not detected in the Phase I, was detected in the south basin sample. PCBs, detected in the Phase I RI, were not detected in any Phase II sediment sample.

- Phase I and II data indicate that migration of contaminants off of the AOC via the exit culvert appears to be minimal or that contaminants have attenuated over time. Phase I and II RI data do not indicate substantial flux of contaminants into EBG from upstream sources through the inlet culverts.

- Duplicate subaqueous multi-increment sediment samples show generally good data reproducibility within a given sample area. Some variation was observed with respect to low concentrations of pesticides in the north basin and explosives in the south basin.

4.5 SURFACE WATER

Eight surface water samples were collected during the Phase II RI to assess the potential for contaminant migration in surface water, to evaluate potential contaminant accumulation areas to be determined if residual contamination is partitioning to water and if these features are acting as secondary sources for contamination to groundwater and surface water, and to evaluate potential contaminant exit pathways from EBG. Data summary statistics and screening results to identify SRCs are presented in Table 4-11.

4.5.1 Summary of Phase I Remedial Investigation Data

The following summarizes the key nature and extent findings from the Phase I RI for surface water at EBG.

- Explosives were detected in surface water primarily in the T-Area. Outside of the T-Area, samples collected from station EBG-114 (PF534), EBG-115 (east inlet), and EBG-120 (downstream of the EBG outlet) contained explosives. The number of detected explosives at any given station was limited to one compound, with the exception of station EBG-086 in the T-Area (three detected explosives). Nitrocellulose was detected on one occasion within the T-Area.

- The occurrence of metals detected above background values was concentrated within the T-Area. The north, west, and south surface water basins and the EBG outlet contained only arsenic, barium, and manganese above background values. The east surface water basin contained multiple metals above background.

- Low concentrations of 4-methylphenol and phenol were clustered in the T-Area. Low concentrations of five VOC compounds were detected at least once with toluene, acetone, and carbon disulfide being the most frequently detected VOCs. The majority of detected VOCs occurred in the T-Area.

- Off-site sampling results show that five explosives were detected at station EBG-114 (PF534). Arsenic, barium, and manganese were above background at EBG-114 and -116 (EBG drainage way). The sample from station EBG-117 (ore pile tributary) contained multiple metals above their background criteria, indicating potential impacts due to surface runoff.

4.5.2 Explosives and Propellants

Explosive compounds were not detected at any of the eight surface water stations sampled during the Phase II RI. The propellant nitrocellulose was detected in the sample collected from station EBG-155, located at the east inlet culvert (see Figure 4-7 for location) at an estimated concentration of 250 µg/L.

The absence of explosives in Phase II surface water samples contrasts with the results of the Phase I samples, which showed explosives in surface water in the vicinity of the T-Area and the east inlet, and outside the AOC at the station just downstream of the EBG outlet and at PF534. The propellant nitrocellulose was also detected in one Phase I sample within the T-Area.

Table 4-11. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Ground Surface Water

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL$_{95}$ of Mean	Exposure Concentration	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Explosives											
Nitrocellulose	9004-70-0	mg/L	1/ 7	1.13E-01	2.50E-01	2.50E-01	1.57E-01	1.57E-01		Yes	Yes
Metals											
Aluminum	7429-90-5	mg/L	7/ 8	1.54E-01	8.66E-02	4.56E-01	3.71E-01	3.71E-01	3.37E+00	No	No
Antimony	7440-36-0	mg/L	7/ 8	6.91E-04	4.20E-04	1.10E-03	9.08E-04	9.08E-04		Yes	Yes
Arsenic	7440-38-2	mg/L	8/ 8	1.01E-03	7.70E-04	1.80E-03	1.25E-03	1.25E-03	3.20E-03	No	No
Barium	7440-39-3	mg/L	8/ 8	2.20E-02	1.54E-02	3.24E-02	2.59E-02	2.59E-02	4.75E-02	No	No
Beryllium	7440-41-7	mg/L	1/ 8	1.18E-05	2.10E-05	2.10E-05	1.43E-05	1.43E-05		Yes	Yes
Cadmium	7440-43-9	mg/L	1/ 8	6.88E-05	1.30E-04	1.30E-04	8.53E-05	8.53E-05		Yes	Yes
Calcium	7440-70-2	mg/L	8/ 8	1.55E+01	1.29E+01	2.66E+01	1.86E+01	1.86E+01	4.14E+01	No	No
Cobalt	7440-48-4	mg/L	4/ 8	1.89E-04	1.90E-04	3.00E-04	2.43E-04	2.43E-04		Yes	Yes
Copper	7440-50-8	mg/L	2/ 8	1.86E-03	3.70E-03	5.20E-03	2.98E-03	2.98E-03	7.90E-03	No	No
Iron	7439-89-6	mg/L	8/ 8	1.69E+00	1.27E+00	2.08E+00	1.86E+00	1.86E+00	2.56E+00	No	No
Lead	7439-92-1	mg/L	5/ 8	1.52E-03	1.40E-03	4.00E-03	6.20E-03	4.00E-03		Yes	Yes
Magnesium	7439-95-4	mg/L	8/ 8	4.22E+00	3.14E+00	6.98E+00	5.22E+00	5.22E+00	1.08E+01	No	No
Manganese	7439-96-5	mg/L	8/ 8	1.41E-01	7.57E-02	2.92E-01	2.35E-01	2.35E-01	3.91E-01	No	No
Nickel	7440-02-0	mg/L	8/ 8	1.20E-03	7.90E-04	1.60E-03	1.37E-03	1.37E-03		Yes	Yes
Potassium	7440-09-7	mg/L	8/ 8	3.56E+00	1.29E+00	6.65E+00	5.43E+00	5.43E+00	3.17E+00	Yes	No
Sodium	7440-23-5	mg/L	8/ 8	7.29E+00	3.29E+00	1.47E+01	1.12E+01	1.12E+01	2.13E+01	No	No
Vanadium	7440-62-2	mg/L	1/ 8	7.38E-04	1.70E-03	1.70E-03	9.98E-04	9.98E-04		Yes	Yes
Zinc	7440-66-6	mg/L	6/ 8	4.88E-03	4.30E-03	9.30E-03	6.44E-03	6.44E-03	4.20E-02	No	No
Organics-Volatile											
1,1,2,2-Tetrachloroethane	79-34-5	mg/L	1/ 8	7.00E-04	2.10E-03	2.10E-03	1.08E-03	1.08E-03		Yes	Yes
Chloromethane	74-87-3	mg/L	2/ 8	4.60E-04	3.00E-04	3.80E-04	5.12E-04	3.80E-04		Yes	Yes
Trichloroethene	79-01-6	mg/L	1/ 8	4.95E-04	4.60E-04	4.60E-04	5.05E-04	4.60E-04		Yes	Yes

[a] One-half of the detection limit was used as a surrogate value for nondetects in the calculation of summary statistics.
[b] Background criteria were set to zero for all organics and inorganics that were not detected in the background dataset.
[c] The essential nutrient screen was not applied for the ecological risk assessment**.**
CAS = Chemical Abstracts Service.
RI = Remedial investigation.
SRC = Site-related contaminant.
UCL$_{95}$ = 95% upper confidence limit.

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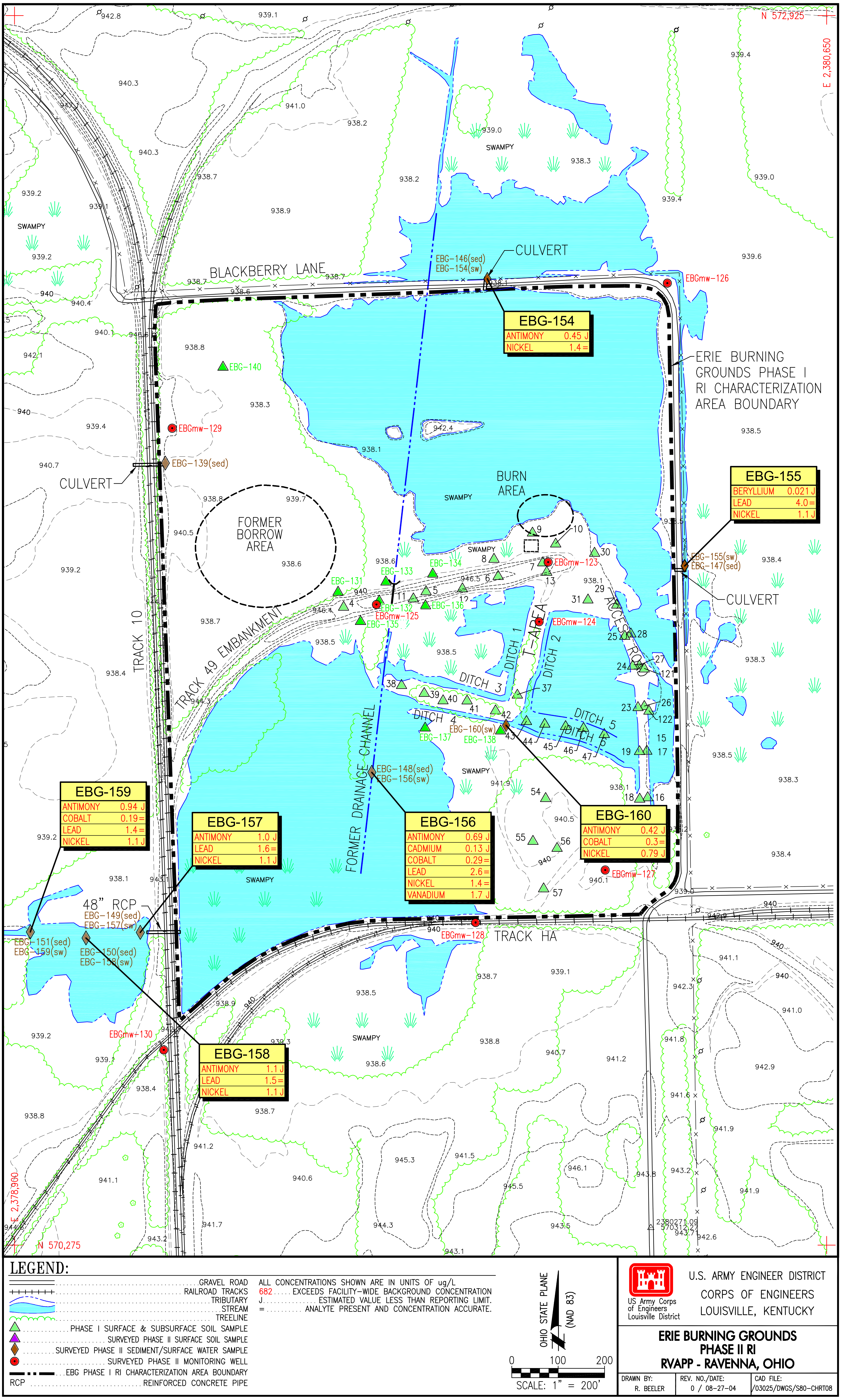

Figure 4-7. Occurrence of Selected Inorganic SRCs in Surface Water, EBG Phase II RI

4.5.3 Inorganic Constituents

A total of 18 metals were detected at least once in surface water during the Phase II RI. The maximum concentrations of aluminum, arsenic, barium, copper, manganese, and zinc did not exceed the facility-wide background concentration and were not identified as SRCs. Thallium was not considered as an SRC due to the high percentage of rejected values. Five of the detected metals were eliminated as potential SRCs because they are normally considered essential elements (calcium, iron, potassium, magnesium, and sodium). Table 4-12 contains analytical data for the seven remaining inorganics identified as SRCs in surface water during the Phase II RI at EBG.

For those metals retained as SRCs, antimony, cobalt, lead, and nickel were detected above background in at least four of the eight samples collected. These four chemicals, in addition to beryllium, cadmium, and vanadium, were not detected in the background data set so background was set to zero. Similar to the Phase II RI sediment results, the greatest occurrence of metals above background values was found at EBG-156 in the former drainage channel in the south basin. Figure 4-7 indicates the distribution of inorganic surface water SRCs based on the Phase II RI results. Not shown on this figure is the EBG-161 station, which corresponds to the PF534 location. This location is indicated on Figure 1-2.

Table 4-12. Inorganic SRCs in Phase II RI Surface Water Samples at Erie Burning Grounds

Analyte (µg/L)	EBG-154 North Inlet	EBG-155 East Inlet	EBG-156 South Basin	EBG-157 EBG Outlet	EBG-158 Below EBG Outlet	EBG-159 Below EBG Outlet	EBG-160 T-Area	EBG-161 PF534
Antimony	0.45 J *		0.69 J *	1.0 J *	1.1 J *	0.94 J *	0.42 J *	0.76 J *
Beryllium		0.021 J *						
Cadmium			0.13 J *					
Cobalt			0.29 = *			0.19 = *	0.3 = *	0.2 = *
Lead		4.0 = *	2.6 = *	1.6 = *	1.5 = *	1.4 = *		
Nickel	1.4 = *	1.1 J *	1.4 = *	1.1 J *	1.1 J *	1.1 J *	0.79 J *	1.6 = *
Vanadium			1.7 J *					

EBG = Erie Burning Grounds.
* - value above facility-wide background criterion.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

No additional surface water SRCs were identified at EBG based on Phase II RI results. The Phase II surface water sample from the south basin (EBG-156) contained six inorganic SRCs above background, relative to the Phase I RI, in which only arsenic, barium, and manganese exceeded background concentrations. The Phase I RI found the majority of surface water contamination in the T-Area and in the east basin. The samples collected at EBG outlet (EBG-157) and stations immediately downstream (EBG-158 and -159), as well as the off-AOC location (EBG-161) at PF534, had few identified SRCs and all SRCs had background values set to zero.

4.5.4 Semivolatile Organic Compounds, Volatile Organic Compounds, and Polychlorinated Biphenyls

SVOCs and PCBs/pesticides were not detected in the Phase II RI surface water samples. Low concentrations of three VOCs, 1,1,2,2-tetrachloroethane, chloromethane, and trichloroethene (TCE) were detected in EBG surface water samples (Table 4-13). The VOCs most frequently detected in the Phase I RI (acetone, toluene, and carbon disulfide) were not detected in Phase II samples. VOCs had not been previously detected at PF534.

Table 4-13. Summary of VOCs in Phase II RI Surface Water Samples at Erie Burning Grounds

Analyte (µg/L)	EBG-155 East Inlet	EBG-160 T-Area	EBG-161 PF534
1,1,2,2-Tetrachloroethane	2.1 =		
Chloromethane		0.38 J	0.3 J
Trichloroethene	0.46 J		

RI = Remedial investigation.
VOC = Volatile organic compound.
= - analyte present and concentration accurate.
J - estimated value less than reporting limits.
Blank cells represent non-detect values.

4.5.5 Summary

Explosive compounds were not detected at the eight surface water stations sampled during the Phase II RI. The propellant nitrocellulose was detected in the Phase II surface water sample collected from the east inlet. The absence of explosives in Phase II surface water samples contrasts with the results of the Phase I samples, which showed explosives in surface water in the vicinity of the T-Area and the east inlet, and outside the AOC at the station just downstream of the EBG outlet and at PF534. Based on Phase II RI results, migration of dissolved-phase explosives off of the AOC in surface water appears to be minimal.

The greatest number of inorganics above background occurred in the surface water sample collected from the former drainage channel in the south basin; few SRCs were observed in this area in the Phase I RI. Inorganics were also detected above background at the EBG outlet (EBG-157) and stations immediately downstream (EBG-158 and -159), as well as the off-AOC location (EBG-161) at PF534.

SVOCs, pesticides, and PCBs were not detected in Phase II surface water samples. It is unclear whether low levels of VOCs detected in Phase II RI samples collected within the T-Area and at the east inlet are related to former AOC operations. VOCs most frequently detected in surface water during the Phase I RI (acetone, toluene, and carbon disulfide) were not detected in Phase II RI samples. VOCs had not been detected previously at the PF534 location.

4.6 GROUNDWATER

Groundwater was not previously characterized at EBG. To address this data gap, eight monitoring wells were installed during the Phase II RI. The wells were installed for the purpose of providing data on general hydrogeologic characteristics and groundwater flow patterns and to evaluate whether contaminants are leaching from known surface soil and sediment contamination areas to groundwater. Data summary statistics and screening results to identify SRCs are presented in Table 4-14.

Table 4-14. Summary Statistics and Determination of Phase II RI SRCs in Erie Burning Grounds Groundwater

Analyte	CAS Number	Units	Results > Detection Limit	Average Result[a]	Minimum Detect	Maximum Detect	UCL_{95} of Mean	Exposure Concentration	MCL	Site Background Criteria[b]	Max Detect > Background	Site Related?[c]
Metals												
Antimony	7440-36-0	mg/L	1/ 8	5.57E-04	3.30E-03	3.30E-03	1.30E-03	1.30E-03	6.0E-03	0	Yes	Yes
Arsenic	7440-38-2	mg/L	8/ 8	1.11E-02	2.20E-03	2.86E-02	4.45E-02	2.86E-02	1.0E-02	1.17E-02	Yes	Yes
Barium	7440-39-3	mg/L	8/ 8	1.24E-01	2.59E-02	2.44E-01	3.54E-01	2.44E-01	2.0E+00	8.21E-02	Yes	Yes
Calcium	7440-70-2	mg/L	8/ 8	7.00E+01	4.81E+01	9.20E+01	8.26E+01	8.26E+01		1.15E+02	No	No
Cobalt	7440-48-4	mg/L	5/ 8	9.34E-04	5.40E-04	4.00E-03	1.57E-01	4.00E-03		0	Yes	Yes
Copper	7440-50-8	mg/L	2/ 8	1.73E-03	1.10E-03	6.80E-03	3.16E-03	3.16E-03	1.3E+00[d]	0	Yes	Yes
Iron	7439-89-6	mg/L	8/ 8	3.82E+00	2.34E-01	8.57E+00	5.83E+00	5.83E+00		2.79E-01	Yes	No
Lead	7439-92-1	mg/L	1/ 8	2.08E-04	3.40E-04	3.40E-04	2.48E-04	2.48E-04	1.5E+00[d]	0	Yes	Yes
Magnesium	7439-95-4	mg/L	8/ 8	1.29E+01	7.28E+00	1.69E+01	1.54E+01	1.54E+01		4.33E+01	No	No
Manganese	7439-96-5	mg/L	8/ 8	2.92E-01	7.24E-02	5.21E-01	6.83E-01	5.21E-01		1.02E+00	No	No
Nickel	7440-02-0	mg/L	8/ 8	1.62E-03	3.50E-04	5.00E-03	5.78E-03	5.00E-03		0	Yes	Yes
Potassium	7440-09-7	mg/L	8/ 8	2.23E+00	9.55E-01	4.92E+00	3.86E+00	3.86E+00		2.89E+00	Yes	No
Sodium	7440-23-5	mg/L	8/ 8	6.15E+00	3.44E+00	1.07E+01	9.20E+00	9.20E+00		4.57E+01	No	No
Vanadium	7440-62-2	mg/L	1/ 8	7.00E-04	1.40E-03	1.40E-03	8.90E-04	8.90E-04		0	Yes	Yes
Zinc	7440-66-6	mg/L	4/ 8	2.84E-02	4.60E-03	1.39E-01	2.84E+00	1.39E-01		6.09E-02	Yes	Yes
Organics-Pesticide/PCB												
4,4'-DDT	50-29-3	mg/L	1/ 8	3.19E-05	4.00E-05	4.00E-05	3.54E-05	3.54E-05		0	Yes	Yes
Organics-Semivolatile												
Bis(2-ethylhexyl)phthalate	117-81-7	mg/L	1/ 8	5.85E-03	2.80E-03	2.80E-03	6.69E-03	2.80E-03	6.0E-03	0	Yes	Yes
Di-n-butyl phthalate	84-74-2	mg/L	2/ 8	6.25E-03	4.20E-03	7.80E-03	6.92E-03	6.92E-03		0	Yes	Yes
Organics-Volatile												
Carbon Disulfide	75-15-0	mg/L	6/ 8	1.12E-03	3.20E-04	4.90E-03	2.16E-03	2.16E-03		0	Yes	Yes

[a] One-half of the detection limit was used as a surrogate value for nondetects in the calculation of summary statistics.

[b] Background criteria were set to zero for all organics and inorganics that were not detected in the background dataset.

[c] The essential nutrient screen was not applied for the ecological risk assessment.

[d] Drinking water action level.

CAS = Chemical Abstracts Service.

DDT = Dichlorodiphenyltrichloroethane.

MCL = Maximum contaminant level.

PCB = Polychlorinated biphenyl.

RI = Remedial investigation.

SRC = Site-related contaminant.

UCL_{95} = 95% upper confidence limit.

4.6.1 Explosives and Propellants

Explosive compounds were not detected in Phase II groundwater samples collected at EBG.

4.6.2 Target Analyte List Metals and Cyanide

Nine inorganic SRCs were detected in at least one of eight monitoring wells (Table 4-15). Six constituents were eliminated as potential groundwater SRCs because they were either considered essential nutrients (calcium, iron, magnesium, potassium, and sodium) or the maximum concentration was less than background (manganese). Although iron concentrations exceed the Ohio secondary MCL of 0.3 mg/L, the facility-wide background value for iron also exceeds the secondary iron standard.

The well with the most metals detected above background criteria was EBGmw-126, located just outside the AOC boundary on the northeast corner. EBGmw-130, located outside the AOC boundary on the southwest corner, had the greatest number of metals detected (six) but only three concentrations exceeded background (cobalt, copper, and nickel), all of which have background values set to zero. Wells EBG-mw-127, located in the wooded area in the southeast portion of the AOC, and EBGmw-123, located on the Track 49 embankment south of the Former Burn Area, each had four metals exceeding background (Figure 4-8). EBGmw-127 contained the maximum concentration of three metals (barium, lead, and zinc) as did EBGmw-130 (cobalt, copper, and nickel).

Correlation between the locations of monitoring wells and presence of inorganic SRCs does not appear to exist. Wells located within the T-Area and Track 49 embankment had similar numbers and concentrations of inorganic SRCs as those located at the AOC boundary (e.g., EBGmw-123 and -130). These observations, together with the fact that explosives were not detected in any groundwater sample, indicates minimal leaching from soil and sediment to groundwater or rapid dilution/attenuation within the shallow groundwater zone due to groundwater-surface water interaction.

4.6.3 Semivolatile Organic Compounds, Volatile Organic Compounds, and Polychlorinated Biphenyls

Few organics were detected in Phase II RI groundwater samples. The SVOC bis(2-ethylhexyl)phthalate was detected at EBGmw-125 and di-n-butyl phthalate was detected at EBGmw-124 and -125. EBGmw-125, which contained the maximum concentration of di-n-butyl-phthalate (4.2 µg/L), is located on the Track 40 embankment southeast of the Former Borrow Area. EBGmw-124 is located on the north leg of the T-Area.

Carbon disulfide was the only VOC detected in groundwater during the Phase II RI (Table 4-16). It was detected in seven of the eight groundwater wells. The highest concentrations were found at EBGmw-124 (4.9 µg/L) located in the T-Area.

One pesticide compound, 4,4’-DDT, was detected at a concentration of 0.04 µg/L at EBGmw-130, located at the southwestern corner of EBG.

Table 4-15. Inorganic SRCs Detected in EBG Phase II RI Groundwater Samples

Analyte (mg/L)	Station							
	EBGmw-123	EBGmw-124	EBGmw-125	EBGmw-126	EBGmw-127	EBGmw-128	EBGmw-129	EBGmw-130
Antimony						0.0033 = *		
Arsenic	0.0286 = *	0.0115 =	0.0181 = *	0.0183 = *	0.0035 =	0.0034 =	0.0032 =	0.0022 =
Barium	0.19 = *	0.146 = *	0.065 =	0.206 = *	0.244 J *	0.0622 =	0.0259 =	0.0491 =
Cobalt	0.00079 = *	0.00059 = *		0.0014 = *		0.00054 = *		0.004 = *
Copper							0.0011 = *	0.0068 = *
Lead					0.00034 J *			
Nickel	0.0025 = *	0.0012 J *	0.00043 J *	0.0016 = *	0.00046 J *	0.0014 = *	0.00035 J *	0.005 = *
Vanadium			0.0014 J *					
Zinc		0.0066 =		0.0719 = *	0.139 = *			0.0046 =

RI = Remedial investigation.
SRC = Site-related contaminant.
= - Analyte present and concentration accurate.
* = Exceeds background criteria.
J - Estimated value less than reporting limits.
Blank cells represent non-detect values.

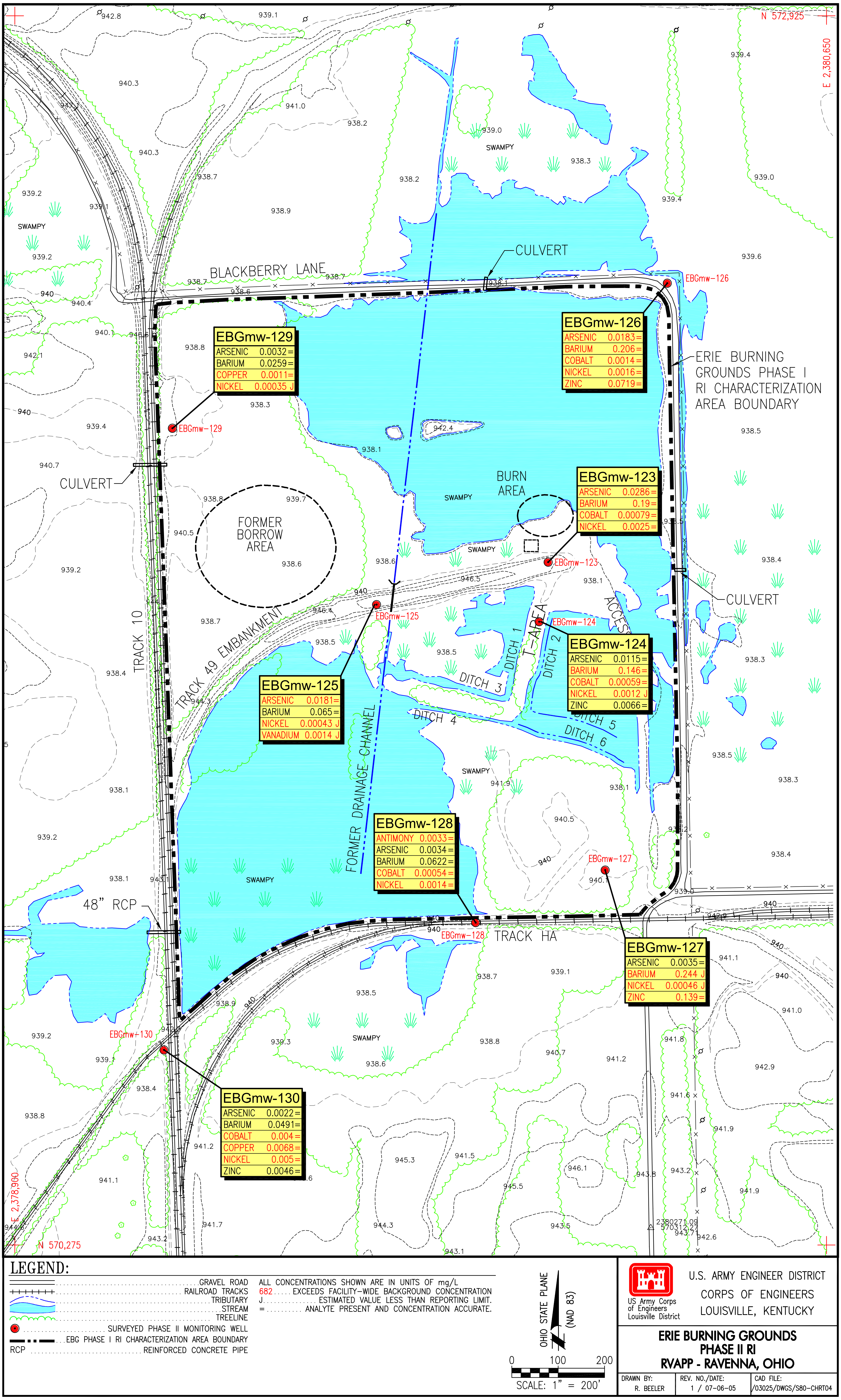

Figure 4-8. Distribution of Selected Inorganics in Groundwater, EBG Phase II RI

Table 4-16. Organic SRCs Detected in Erie Burning Grounds Phase II RI Groundwater Samples

	EBGmw-123	**EBGmw-124**	**EBGmw-125**	**EBGmw-127**	**EBGmw-128**	**EBGmw-129**	**EBGmw-130**
Pesticides/PCBs (µg/L)							
4,4'-DDT							0.04 J
SVOCs (µg/L)							
Bis(2-ethylhexyl)phthalate			2.8 J				
Di-n-butyl phthalate		7.8 J	4.2 J				
VOCs (µg/L)							
Carbon Disulfide	0.36 J	4.9 =	0.49 J	1.2 =	0.66 J	0.32 J	

DDT = Dichlorodiphenyltrichlorethane.
PCB = Polychlorinated biphenyl.
RI = Remedial investigation.
SRC = Site-related contaminant.
SVOC = Semivolatile organic compound.
VOC = Volatile organic compound.
“=” = Analyte present and concentration accurate.
= Analyte exceeds background criteria.
J = Estimated value is less than the reporting limits.
Blank cells represent non-detect values.

4.6.4 Summary

The absence of explosives in groundwater during the Phase II RI indicates that leaching of explosives contamination in soils and sediments to groundwater is minimal or that dilution factors are high. Nine inorganics were identified as groundwater SRCs (antimony, arsenic, barium, cobalt, copper, lead, nickel, vanadium, and zinc). Arsenic was present at values exceeding the MCL but this metal, along with other inorganic SRCs, is pervasive throughout RVAAP soils, sediment, surface water, and groundwater. Metals were detected above background criteria as often in wells located outside the AOC boundary on the northeast and southwest corner of EBG as in wells located in the center of known surface soil and sediment contamination. In addition to explosives, organic contaminants were largely absent in Phase II RI groundwater samples.

In summary, it appears that the migration of contaminants from soils and sediment to groundwater beneath EBG is limited. Although some metals are present above facility-wide background concentrations, the number of metal SRCs in groundwater compared to those present in soils is substantially less. Of the constituent concentrations detected in groundwater, none exceeds a current primary drinking water maximum contaminant level (MCL). Iron and manganese exceeded their respective non-enforceable secondary MCLs at all eight monitoring wells.

4.7 ORDNANACE AND EXPLOSIVES AVOIDANCE SURVEY SUMMARY

MEC technicians provided OE avoidance training and support during all field operations. The OE avoidance crew cleared all soil and monitoring well drilling locations within the EBG AOC. No OE was discovered during field reconnaissance and magnetometer surveys of access routes and proposed sampling or drilling. In several instances, subsurface magnetic anomalies resulted in the decision to move pre-planned sample locations short distances to points where no anomalies were observed. Appendix L contains the full OE avoidance report for the EBG Phase II RI.

4.8 SUMMARY OF CONTAMINANT NATURE AND EXTENT

Based on the evaluation of Phase II RI data, the following conclusions can be made on the nature, occurrence, and distribution of contaminants in environmental media at EBG.

Surface Soil

- The results of the Phase II RI identified low levels of four additional explosive compounds in addition to 2,4,6-TNT, which was detected in the Phase I RI. The occurrence of explosives and propellants in the Phase II was similar to the Phase I, with most explosives detected along the north and south sides of the Track 49 embankment. Although the extent of explosive contamination was not defined to detection limits by Phase II RI sampling, the areas exhibiting the greatest numbers and concentrations of explosives appear to have been identified and delineated.

- Inorganic SRCs were pervasive in Phase II RI soil samples, similar to the Phase I results. Sample locations along the north side of the Track 49 embankment typically contained the highest number and concentrations in EBG-134. At the north exit culvert beneath Track 10 on the western side of EBG, ten SRCs were identified, including the maximum concentration of beryllium.

- SVOCs bis(2ethylhexyl)phthalate and PAHs were detected most frequently and at the highest concentrations to the north and south of the Track 49 embankment, with EBG-133 showing the maximum concentration for most compounds. Toluene was detected at low concentrations in two stations (EBG-131 and -132) along Track 49.

Sediment

- Explosives or propellants were not detected in Phase II sediment samples downstream of the EBG outlet. Flux of explosives into EBG from upstream areas and migration of explosive contaminants in sediment off of the AOC appears to be minimal.

- Inorganics above background concentrations were routinely detected within the EBG south surface water basin, at the north and east inlets, and downstream of the EBG outlet. This distribution somewhat contrasts the Phase I RI results where the south basin was identified as an area of only minor inorganic contamination during the Phase I RI. Metals were also not detected above background at locations downstream of the EBG outlet in the earlier investigation. Beryllium was detected above background in five of six Phase II sediment samples; this metal was not identified as a SRC in the Phase I RI.

- Few SVOCs, VOCs, and pesticides were detected in Phase II RI sediment samples and all detects were of low concentration. PCBs, detected in the Phase I RI, were not detected in any Phase II sediment sample.

- Phase I and II data indicate that migration of contaminants off of the AOC via the exit culvert appears to be minimal or that contaminants have attenuated over time. Phase I and II RI data do not indicate substantial flux of contaminants into EBG from upstream sources through the inlet culverts.

- Qualitative review of the application of multi-increment sampling techniques to subaqueous sediments indicates that the method appears to produce representative data with a high degree of reproducibility.

Surface Water

- Explosive compounds were not detected at the eight surface water stations sampled during the Phase II RI. The propellant nitrocellulose was detected at low concentrations in the Phase II surface water sample collected from the east inlet. Based on Phase II RI results, migration of dissolved-phase explosives off of the AOC in surface water appears to be minimal.

- Seven metals were detected above background criteria at least once in Phase II surface water samples, including antimony, beryllium, cadmium, cobalt, lead, nickel, and vanadium. All of these constituents were identified as SRCs by virtue of the fact that the background criteria are set to zero.

- SVOCs, pesticides, and PCBs were not detected in Phase II surface water samples. VOCs observed in Phase II RI samples may or may not be related to former AOC operations based on detection frequency and the fact that the chemicals most frequently detected in the Phase I (acetone, toluene, and carbon disulfide) were not detected in Phase II samples.

Groundwater

- The absence of explosives in groundwater during the Phase II RI indicates that leaching of explosives contamination present in soils and sediment to the groundwater table is minimal or that dilution factors are very high.

- Inorganics were detected above background criteria as often in wells located outside the AOC boundary to the northeast and southwest corners of EBG, as in wells located in the center of known surface soil and sediment contamination. Maximum concentrations ranged from 2 to 3 times background when background criteria were above zero.

- Few organic compounds (SVOCs, VOCs, pesticides/PCBs) were detected in monitoring wells during the Phase II RI.

In general, the Phase II RI achieved its objective of further understanding the nature and extent of contamination at within EBG. In particular, the Phase II RI data demonstrate that migration of contaminants (dissolved phase or sediment bound) off of the AOC via the principal exit drainage is minimal. Some potential accumulation of inorganic SRCs at levels above background criteria in sediments downstream of the EBG outlet was noted. Based on these data, the potential for vegetative biouptake, dilution, and sorption within the extensive EBG wetland areas is presumed to be very high. Likewise, high dilution/attenuation factors are presumed to result in few groundwater contaminants above background levels.

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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 EBG. 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 detected at EBG). Section 5.3 presents a conceptual model for contaminant fate and transport at EBG 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 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 the transport media at EBG are summarized in Tables J-1, J-2, and J-3 of Appendix J. 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:

$$-dC/dt = kC \,, \tag{5-1}$$

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 EBG 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

ρb = the soil bulk dry density, (g/cm^3),
ϕw= 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 EBG 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 EBG. 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 TNB and 1,3-dinitrobenzene 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 2004) 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. 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 EBG for fate and transport analysis. The predictive function of the CSM, which is of primary

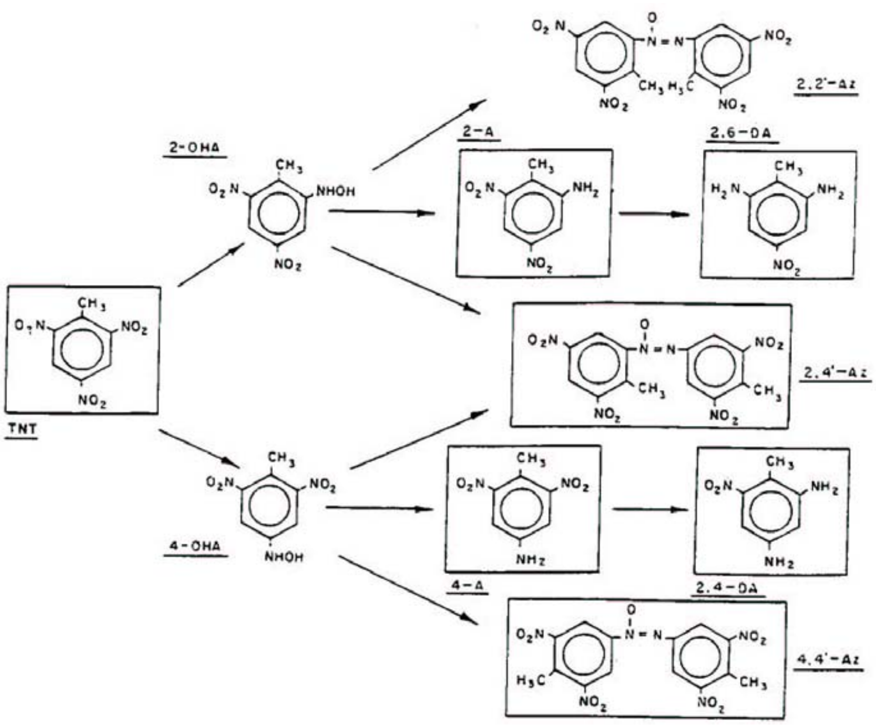

Figure 5-1. 2,4,6-TNT Biotransformation Pathway

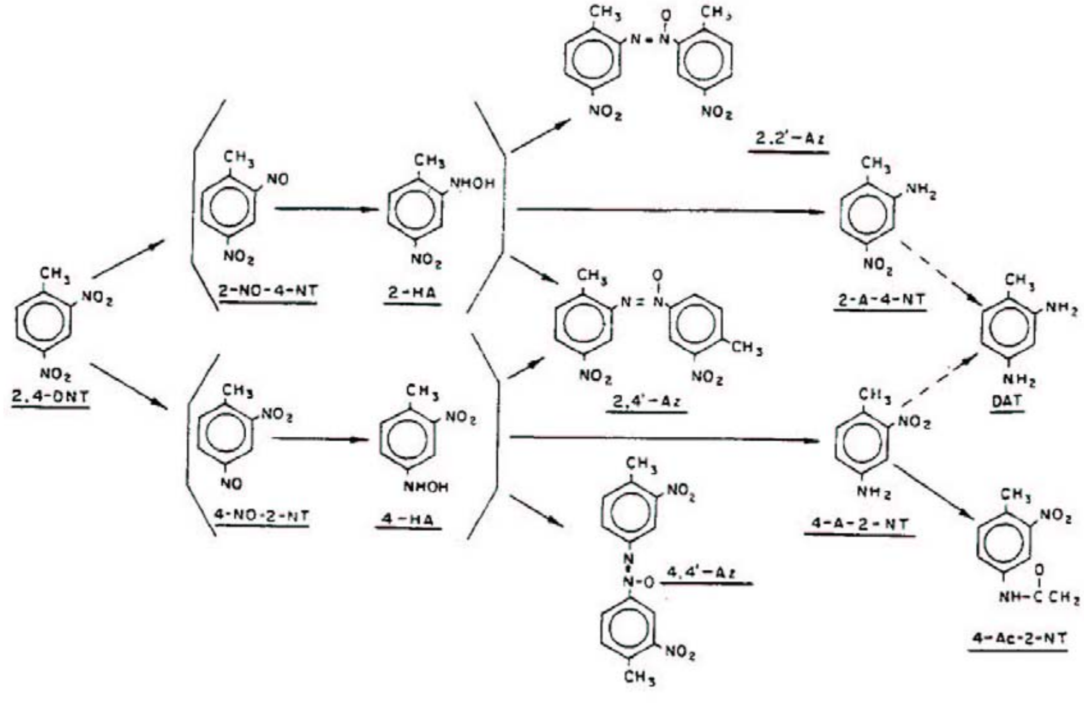

Figure 5-2. 2,4-DNT Biotransformation Pathway

importance to contaminant fate and transport analysis, relies on known information and informed 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 is provided below.

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 EBG. Numerous inorganic SRCs were identified in these areas: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, mercury, nickel, silver, thallium, vanadium, and zinc. Organic SRCs identified were primarily PAHs. Explosive and propellants identified as SRCs were: 1,3,5-TNB 2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; 3-nitrotoluene; 4-nitrotoluene; 4-amino-2,6-DNT; HMX; nitrocellulose; and RDX.

- Metals and low concentrations of a few organics are present in the groundwater below EBG. Metal SRCs identified in the groundwater are antimony, arsenic, barium, cobalt, copper, lead, nickel, vanadium, and zinc. Organic SRCs identified are 4,4'-DDT, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, and carbon disulfide.

The source area was selected considering Phase I and Phase II surface and subsurface soil samples near the Track 49 embankment. An area 600 x 150 ft containing EBGmw-125 on the west and EBGmw-123 on the east was considered. This area is shown schematically on Figure 8-1.

5.3.2 Hydrogeology

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

- Elevations across EBG vary from approximately 286 to 289 m (938 to 947 ft) amsl. In general, the Track 49 embankment is elevated approximately 2.4 m (8 ft) relative to the pond’s surface.

- EBG is situated within a band of glacial outwash deposits. Soil of the Sebring series silt loams is dominant. In particular, silty clays and silty sands dominate. These soil types are associated with level to gently sloping, poorly drained soil of locustrine or floodplain alluvial origin. Surface soil is dominated by silty clays and silty sands. Thus, the somewhat impervious surface material is underlain by more permeable zones or layers.

- Groundwater flow varies below EBG. Flow direction varies from southward to eastward. The direction is estimated to be southeast below the Track 49 embankment. The elevation of the groundwater table varies from 937 to 939 ft amsl at EBG.

- Contaminant concentrations are highest within a discrete zone [0 to 0.3-m (0 to 1-ft) surface soil interval]. Contaminant leaching pathways from soil to the water table are through the soil cover. A soil layer (approximately 7 ft thick) is present below Track 49 embankment.

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 EBG, 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. Explosives were not detected in groundwater samples; therefore, chemical decay and attenuation rates exceed leaching rates.

Release by gaseous emissions and airborne particulates is not significant at EBG. VOCs were not found at significant concentrations in surface soil or sediments. 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 EBG. 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 EBG 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 EBG 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 Erie Burning Grounds

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 EBG generally have sufficient organic carbon content to cause retardation of organic constituents. 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 selection of a source area aggregate for modeling. The source aggregate selected for EBG was the Track 49 embankment, which was delineated by sampling locations along the crest and north and south embankment slopes.

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 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 1996a). A DAF of 10.0 was estimated following EPA guidelines (1996a) and applied to the GSSLs. As described in the EPA Soil Screening Guidance documentation (EPA 1996a), 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).

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

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

Table 5-1. Unit-Specific Parameters Used in SESOIL and AT123D Modeling for Erie Burning Grounds

Parameters	Symbol	Units	Value	Source for Value
SESOIL				
Percolation Rate (Recharge Rate)	q	m/yr	9.45E-02	0.1 * SESOIL Precipitation
Horizontal Area of Aggregate	A_p	sq. m	8,360	Estimated from soil aggregate[a]
Intrinsic Permeability - clayey sand	p	cm^2	9.3E-11	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	6.90E-03	Site-specific data
Bulk Density	ρ_b	kg/L	1.97	Site-specific geotechnical data[b]
Porosity - total	n_T	unitless	0.32	Site-specific geotechnical data[b]
Vadose Zone Thickness	Vz	m	7	Based on water level data
Leaching Zone Thickness	Th	m	6	Based on soil contamination and water level data
AT123D				
Aquifer Thickness	h	m	6	Load Line 1c
Hydraulic Conductivity in Saturated Zone	K_S	cm/s	5.3E-04	Site-specific slug test datad
Hydraulic Gradient in Saturated Zone	I_S	m/m	2.00E-03	Groundwater surface map in work plan*e*
Effective Porosity	n_e	unitless	0.2	Assumed for silt*f*
Distance to the Compliance Point	X	m	0	Beneath the source
Dispersivity, longitudinal	α_L	m	9	Assumed
Dispersivity, transverse	α_T	m	3	0.3 α_L
Dispersivity, vertical	α_V	m	0.9	0.1 α_L
Retardation Factor	R_d	unitless	chemical-specific	See Table J-15

[a] An area 182.9 x 45.7 m = 8,360 m^2 (approximately) containing EBGmw-125 on the west and EBGmw-123 on the east was considered.

[b] Site-specific geotechnical data are provided in Appendix I.

[c] EBG is near Load Line 1. Therefore, The aquifer thickness was based on Load Line 1 input value for AT123D modeling.

[c] The hydraulic conductivity was based on the geomean of the slug test values for MW-123 through MW-130.

[c] The hydraulic gradient was based on the observed gradient between EBGmw-127 and EBGmw-129.

[v] The hydraulic conductivity was estimated as 5.3E-4 cm/sec. This value suggests the subsurface to be silt/sand (Mills et al. 1985). The subsurface was assumed to be silt.

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

SESOIL = Seasonal Soil Compartment model.

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

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. Generally, if contaminant concentrations in soil fall below the GSSL, and there are no significant ecological receptors of concern, then no further study or action is warranted for that area. 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 (1996a), a calculated GSSL was developed using the following equation (EPA 1996a):

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

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 (1996a) 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 J-5 in Appendix J, include metals, explosive compounds, and VOCs.

In the fourth step, the initial CMCOPCs from EBG 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 1996a). 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 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 EBG, 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 the AT123D model, the selected receptor is the south surface water basin. Because the south basin is immediately adjacent to the Track 49 embankment, the transport distance is negligible. Therefore, the AT123D model was used to predict the concentration in groundwater after dilution due to hydrodynamic dispersion and mixing with no lateral migration.

5.5.1 Modeling Approach

Contaminant transport in the vadose zone includes the movement of water and dissolved materials from the source area at EBG to groundwater. This occurs as rainwater infiltrates from the surface and percolates through the area of contamination, and its surrounding soil, 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 (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. 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 model. It computes the spatial-temporal concentration distribution of wastes in the aquifer system and

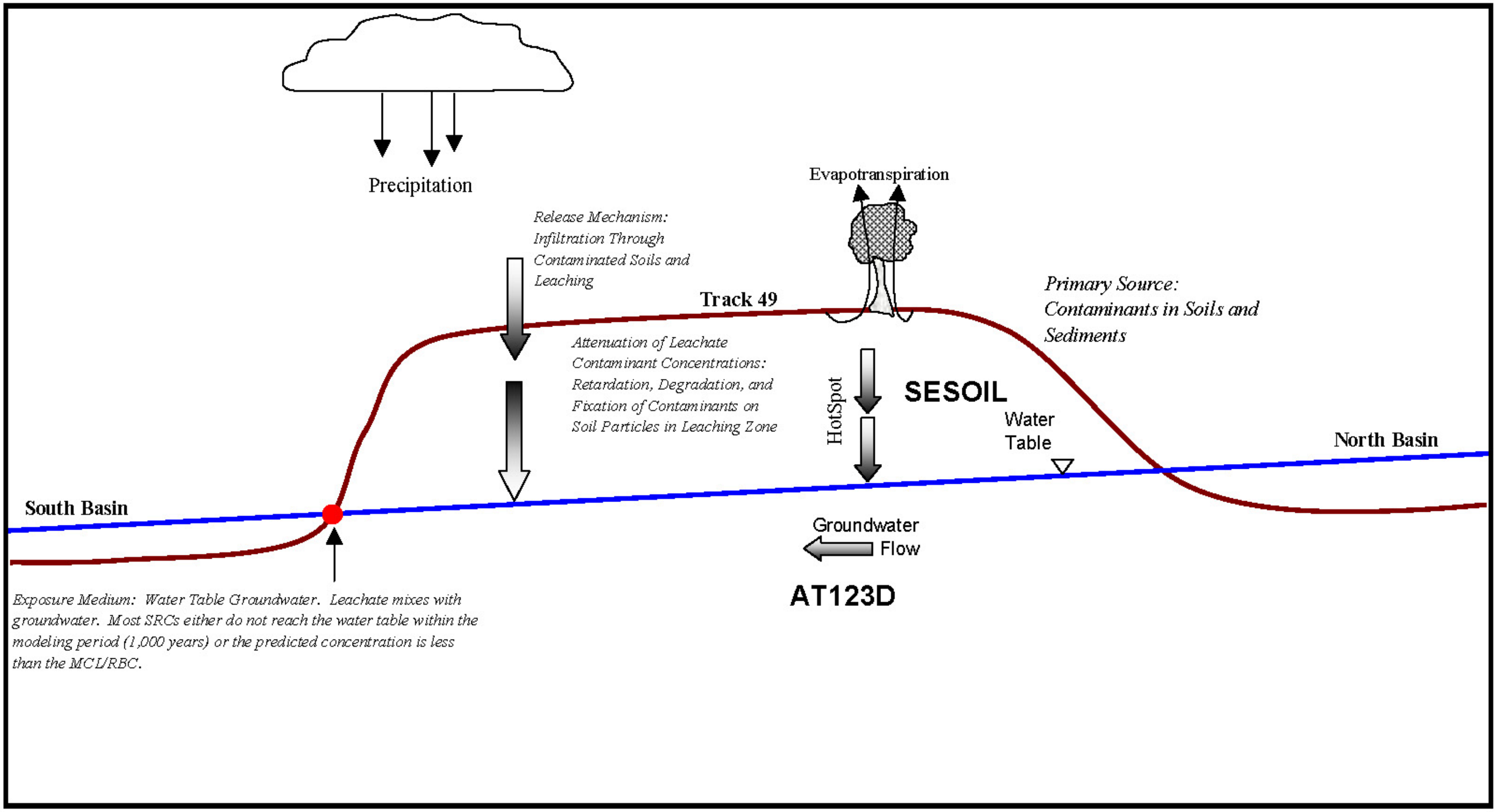

Figure 5-3. Contaminant Migration Conceptual Model

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 high 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 = porewater 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 is 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 J-9 and J-10 of Appendix J. 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 J (Table J-8). The distribution coefficients (K_ds) for metals were obtained from EPA's Soil Screening Guidance Document (EPA 1996a) 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 1996a), unless stated otherwise. Biodegradation rates are not applicable for the inorganic CMCOPCs. 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 3-nitrotoluene; 4-nitrotoluene; and RDX (Table J-8). 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 J (Table J-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 contaminant migration contaminants of concern (CMCOCs).

Table 5-2. Summary of Leachate Modeling Results for the Erie Burning Grounds

Initial CMCOPC	RME 0 to 1 ft (mg/kg)	Predicted $C_{leachate,max}$		Predicted $C_{gw,max}$ At the Source[a] (mg/L)	Observed $C_{gw,max}$ Downgradient of Source (mg/L)	MCL/RBC (mg/L)	Final CM COPC[b]
		Beneath the Source (mg/L)	Predicted Tmax (years)				
Explosives							
2,4-Dinitrotoluene	1.31E-01	3.45E-06	14	2.35E-06	ND	7.30E-02	
2,6-Dinitrotoluene	1.00E-01	3.41E-05	11	2.32E-05	ND	3.60E-02	
3-Nitrotoluene	1.26E-01	2.94E-02	41	2.00E-02	ND	6.10E-02	
4-Nitrotoluene	1.26E-01	4.43E-02	25	3.01E-02	ND	6.10E-02	
RDX	2.58E-01	7.16E-01	4	4.87E-01	ND	6.10E-04	Yes
Metals							
Arsenic	9.56E+00	1.39E-01	614	9.48E-02	2.86E-02	1.00E-02	Yes
Chromium	1.98E+01	4.59E-01	407	3.12E-01	ND	1.00E-01	Yes
Organics-Volatile							
Methylene Chloride	3.80E-03	3.35E-07	4	2.28E-07	ND	5.00E-03	

[a] The concentration was calculated using dilution attenuation factor = 1.47.

[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 concern.

MCL = Maximum contaminant level.

ND = Not detected.

RBC = Risk-based concentration.

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

RME = Reasonable maximum exposure.

Table 5-3. Summary of Groundwater Modeling Results for Erie Burning Grounds

Final CMCOPC	Source / Receptor Concentration (mg/L)	Observed $C_{gw,max}$ (mg/L)	MCL/RBC (mg/L)	CMCOC[a]
Explosives				
RDX	2.19E-01[a]	ND	6.10E-04	Yes
Metals				
Arsenic	5.13E-02[a]	2.86E-02	1.00E-02	Yes
Chromium	1.68E-01[a]	ND	1.00E-01	Yes

[a] The concentration was re-calculated using SESOIL-AT123D model.
CMCOC = Contaminant migration constituent of concern.
CMCOPC = Contaminant migration constituent of potential concern.
MCL = Maximum contaminant level.
ND = Not detected.
RBC = Risk-based concentration.
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 (Table 5-2). The modeling was performed for 2,4-DNT; 2,6-DNT; 3-nitrotoluene; 4-nitrotoluene; RDX; arsenic; chromium; and methylene chloride. 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 downgradient of the source and drinking water MCLs or RBCs (if no MCL is available). Due to the variable groundwater gradient at the site, all wells were considered downgradient from the source so that the highest groundwater concentration measured was taken as the downgradient groundwater concentration. The table shows that RDX, arsenic, and chromium were predicted to exceed MCLs or RBCs beneath the source area. Therefore, these three constituents were selected as the final CMCOPCs for lateral migration. It is noted that the modeled time frame to attain peak RDX leachate concentrations is only 4 years. Given the time of operations at EBG and introduction of contaminants to the source, the peak concentrations have likely passed.

Table 5-3 shows the final CMCOPCs selected for lateral migration using AT123D. Table 5-3 presents the predicted groundwater concentration at the selected receptor location. RDX, arsenic, and chromium were predicted to exceed MCLs/RBCs at the basin edge 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 along 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 7 ft bgs (SESOIL modeling depth). Therefore, the saturated groundwater flow was assumed to occur through unconsolidated material (Figure 5-3). Given AT123D limitation, the hydraulic conductivity field for the saturated zone was assumed homogeneous, and its geometric mean value of 1.3E-02 cm/sec based on the slug-test results (Table 2-1) was used in this modeling. Noting the conductivity to range from 6.79E-04 to 1.39E-01 cm/sec, the predicted concentrations appear to represent a mean condition within a range of expected concentrations. The range appears to be orders 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 relatively narrow range below the facility (Figure 2-4). Therefore, the impact of hydraulic gradient is expected to be relatively 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 Group (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 and subsurface soil at EBG. Among the metals, only arsenic was detected in groundwater exceeding its MCL. Fate and transport modeling indicate that some of the contaminants may leach from contaminated soils into the groundwater beneath the source. Migration of many of the constituents is, however, likely to be attenuated because of moderate to high retardation factors in the unconsolidated materials and high dilution factors upon reaching the saturated zone. Conclusions of the leachate and groundwater modeling are as follows.

- 3-Nitrotoluene; 4-nitrotoluene; 2,4-DNT; 2,6-DNT; RDX; antimony; arsenic; chromium; and methyl chloride were identified as initial CMCOPCs for EBG based on soil screening analyses.

- RDX, arsenic, and chromium were identified as final CMCOPCs for EBG based on source loading predicted by the SESOIL modeling.

- RDX, arsenic, and chromium were identified as CMCOCs based on AT123D modeling. The maximum groundwater concentrations of these constituents were predicted to exceed MCLs/RBCs below the source.

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 EBG. This HHRA 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.

The methodology presented in the FWHHRAM is based on *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989a and 1991a) 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 1997a); Integrated Risk Information System (IRIS) (EPA 2005, updated approximately monthly); and Health Effects Assessment Summary Tables (HEAST) (EPA 1997b). 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 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 the EBG 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. 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 EBG 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 EBG. The data evaluation process is conducted in accordance with the FWHHRAM (USACE 2004b). The purpose of the HHRA data evaluation screening process is to eliminate chemicals for which no further risk evaluation is needed.

A summary of available data is presented in Sections 1.3.3 and 4.1. Data collected at EBG are aggregated by environmental medium (e.g., surface soil). Samples included in the HHRA data sets for shallow surface soil, deep surface soil, subsurface soil, sediment, surface water, and groundwater are listed in Tables 6-1 through 6-6, respectively. A description of the media for which human receptors are potentially exposed follows.

Table 6-1. Human Health Risk Assessment Data Set for Shallow Surface Soil
Erie Burning Grounds

Station	Sample ID	Depth (ft bgs)
EBG-001	EBG001	0 to 1
EBG-002	EBG002	0 to 1
EBG-003	EBG003	0 to 1
EBG-004	EBG005	0 to 1
EBG-005	EBG007	0 to 1
EBG-006	EBG009	0 to 1
EBG-007	EBG011	0 to 1
EBG-008	EBG013	0 to 1
EBG-009	EBG015	0 to 1
EBG-010	EBG017	0 to 1
EBG-011	EBG019	0 to 1
EBG-012	EBG021	0 to 1
EBG-013	EBG023	0 to 1
EBG-014	EBG025	0 to 1
EBG-015	EBG027	0 to 1
EBG-016	EBG029	0 to 1
EBG-017	EBG031	0 to 1
EBG-018	EBG033	0 to 1
EBG-019	EBG035	0 to 1
EBG-020	EBG037	0 to 1
EBG-021	EBG039	0 to 1
EBG-022	EBG041	0 to 1
EBG-023	EBG043	0 to 1
EBG-024	EBG045	0 to 1
EBG-025	EBG047	0 to 1
EBG-026	EBG049	0 to 1
EBG-027	EBG051	0 to 1
EBG-028	EBG053	0 to 1
EBG-029	EBG055	0 to 1
EBG-030	EBG057	0 to 1
EBG-031	EBG059	0 to 1
EBG-032	EBG061	0 to 1
EBG-033	EBG063	0 to 1
EBG-034	EBG065	0 to 1
EBG-035	EBG067	0 to 1
EBG-036	EBG069	0 to 1
EBG-037	EBG071	0 to 1
EBG-038	EBG073	0 to 1
EBG-039	EBG075	0 to 1
EBG-040	EBG077	0 to 1
EBG-041	EBG079	0 to 1
EBG-042	EBG081	0 to 1
EBG-043	EBG083	0 to 1

Table 6-1. Human Health Risk Assessment Data Set for Shallow Surface Soil Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)
EBG-044	EBG085	0 to 1
EBG-045	EBG087	0 to 1
EBG-046	EBG089	0 to 1
EBG-047	EBG091	0 to 1
EBG-048	EBG093	0 to 1
EBG-049	EBG094	0 to 1
EBG-050	EBG095	0 to 1
EBG-051	EBG096	0 to 1
EBG-052	EBG097	0 to 1
EBG-053	EBG098	0 to 1
EBG-054	EBG099	0 to 1
EBG-055	EBG101	0 to 1
EBG-056	EBG103	0 to 1
EBG-057	EBG105	0 to 1
EBG-121	EBG004	0 to 2
EBG-122	EBG064	0 to 2
EBG-131	EBG291	0 to 1
EBG-132	EBG292	0 to 1
EBG-133	EBG293	0 to 1
EBG-134	EBG294	0 to 1
EBG-135	EBG295	0 to 1
EBG-136	EBG296	0 to 1
EBG-137	EBG297	0 to 1
EBG-138	EBG298	0 to 1
EBG-139	EBG299	0 to 0.5
EBG-140	EBG300	0 to 1

bgs = Below ground surface.

Table 6-2. Human Health Risk Assessment Data Set for Deep Surface Soil Erie Burning Grounds

Station	Sample ID	Depth (ft bgs)
EBG-001	EBG001	0 to 1
EBG-002	EBG002	0 to 1
EBG-003	EBG003	0 to 1
EBG-004	EBG005	0 to 1
EBG-004	EBG006	1 to 2.5
EBG-005	EBG007	0 to 1
EBG-005	EBG008	1 to 3
EBG-006	EBG009	0 to 1
EBG-006	EBG010	1 to 3
EBG-007	EBG011	0 to 1
EBG-007	EBG012	1 to 3

Table 6-2. Human Health Risk Assessment Data Set for Deep Surface Soil Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)
EBG-008	EBG013	0 to 1
EBG-008	EBG014	1 to 3
EBG-009	EBG015	0 to 1
EBG-009	EBG016	1 to 3
EBG-010	EBG017	0 to 1
EBG-010	EBG018	1 to 3
EBG-011	EBG019	0 to 1
EBG-011	EBG020	1 to 3
EBG-012	EBG021	0 to 1
EBG-012	EBG022	1 to 3
EBG-013	EBG023	0 to 1
EBG-013	EBG024	1 to 3
EBG-014	EBG025	0 to 1
EBG-015	EBG027	0 to 1
EBG-016	EBG029	0 to 1
EBG-016	EBG030	1 to 3
EBG-017	EBG031	0 to 1
EBG-017	EBG032	1 to 3
EBG-018	EBG033	0 to 1
EBG-018	EBG034	1 to 3
EBG-019	EBG035	0 to 1
EBG-019	EBG036	1 to 3
EBG-020	EBG037	0 to 1
EBG-021	EBG039	0 to 1
EBG-022	EBG041	0 to 1
EBG-023	EBG043	0 to 1
EBG-023	EBG044	1 to 3
EBG-024	EBG045	0 to 1
EBG-024	EBG046	1 to 3
EBG-025	EBG047	0 to 1
EBG-025	EBG048	1 to 3
EBG-026	EBG049	0 to 1
EBG-026	EBG050	1 to 3
EBG-027	EBG051	0 to 1
EBG-027	EBG052	1 to 3
EBG-028	EBG053	0 to 1
EBG-028	EBG054	1 to 3
EBG-029	EBG055	0 to 1
EBG-029	EBG056	1 to 3
EBG-030	EBG057	0 to 1
EBG-030	EBG058	1 to 3
EBG-031	EBG059	0 to 1
EBG-031	EBG060	1 to 3

Table 6-2. Human Health Risk Assessment Data Set for Deep Surface Soil Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)		
EBG-032	EBG061	0	to	1
EBG-033	EBG063	0	to	1
EBG-034	EBG065	0	to	1
EBG-035	EBG067	0	to	1
EBG-036	EBG069	0	to	1
EBG-037	EBG071	0	to	1
EBG-037	EBG072	1	to	3
EBG-038	EBG073	0	to	1
EBG-038	EBG074	1	to	3
EBG-039	EBG075	0	to	1
EBG-039	EBG076	1	to	3
EBG-040	EBG077	0	to	1
EBG-040	EBG078	1	to	3
EBG-041	EBG079	0	to	1
EBG-041	EBG080	1	to	3
EBG-042	EBG081	0	to	1
EBG-042	EBG082	1	to	3
EBG-043	EBG083	0	to	1
EBG-043	EBG084	1	to	3
EBG-044	EBG085	0	to	1
EBG-044	EBG086	1	to	3
EBG-045	EBG087	0	to	1
EBG-045	EBG088	1	to	3
EBG-046	EBG089	0	to	1
EBG-046	EBG090	1	to	3
EBG-047	EBG091	0	to	1
EBG-047	EBG092	1	to	3
EBG-048	EBG093	0	to	1
EBG-049	EBG094	0	to	1
EBG-050	EBG095	0	to	1
EBG-051	EBG096	0	to	1
EBG-052	EBG097	0	to	1
EBG-053	EBG098	0	to	1
EBG-054	EBG099	0	to	1
EBG-054	EBG100	1	to	3
EBG-055	EBG101	0	to	1
EBG-055	EBG102	1	to	3
EBG-056	EBG103	0	to	1
EBG-056	EBG104	1	to	3
EBG-057	EBG105	0	to	1
EBG-057	EBG106	1	to	3
EBG-121	EBG004	0	to	2
EBG-121	EBG038	2.5	to	3
EBG-121	EBG068	2	to	2.5

Table 6-2. Human Health Risk Assessment Data Set for Deep Surface Soil Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)
EBG-122	EBG042	2 to 2.5
EBG-122	EBG064	0 to 2
EBG-122	EBG066	2.5 to 3
EBG-131	EBG291	0 to 1
EBG-132	EBG292	0 to 1
EBG-133	EBG293	0 to 1
EBG-134	EBG294	0 to 1
EBG-135	EBG295	0 to 1
EBG-136	EBG296	0 to 1
EBG-137	EBG297	0 to 1
EBG-138	EBG298	0 to 1
EBG-139	EBG299	0 to 0.5
EBG-140	EBG300	0 to 1

bgs = Below ground surface.

Table 6-3. Human Health Risk Assessment Data Set for Subsurface Soil Erie Burning Grounds

Station	Sample ID	Depth (ft bgs)
EBG-004	EBG006	1 to 2.5
EBG-005	EBG008	1 to 3
EBG-006	EBG010	1 to 3
EBG-007	EBG012	1 to 3
EBG-008	EBG014	1 to 3
EBG-009	EBG016	1 to 3
EBG-010	EBG018	1 to 3
EBG-011	EBG020	1 to 3
EBG-012	EBG022	1 to 3
EBG-013	EBG024	1 to 3
EBG-016	EBG030	1 to 3
EBG-017	EBG032	1 to 3
EBG-018	EBG034	1 to 3
EBG-019	EBG036	1 to 3
EBG-023	EBG044	1 to 3
EBG-024	EBG046	1 to 3
EBG-025	EBG048	1 to 3
EBG-026	EBG050	1 to 3
EBG-027	EBG052	1 to 3
EBG-028	EBG054	1 to 3
EBG-029	EBG056	1 to 3
EBG-030	EBG058	1 to 3
EBG-031	EBG060	1 to 3

Table 6-3. Human Health Risk Assessment Data Set for Subsurface Soil Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)
EBG-037	EBG072	1 to 3
EBG-038	EBG074	1 to 3
EBG-039	EBG076	1 to 3
EBG-040	EBG078	1 to 3
EBG-041	EBG080	1 to 3
EBG-042	EBG082	1 to 3
EBG-043	EBG084	1 to 3
EBG-044	EBG086	1 to 3
EBG-045	EBG088	1 to 3
EBG-046	EBG090	1 to 3
EBG-047	EBG092	1 to 3
EBG-054	EBG100	1 to 3
EBG-055	EBG102	1 to 3
EBG-056	EBG104	1 to 3
EBG-057	EBG106	1 to 3
EBG-121	EBG038	2.5 to 3
EBG-121	EBG068	2 to 2.5
EBG-122	EBG042	2 to 2.5
EBG-122	EBG066	2.5 to 3

bgs = Below ground surface.

Table 6-4. Human Health Risk Assessment Data Set for Sediment Erie Burning Grounds

Station	Sample ID	Depth (ft bgs)
EBG-058	EBG107	0 to 0.5
EBG-058	EBG109	0 to 0.5
EBG-059	EBG110	0 to 0.5
EBG-059	EBG112	0 to 0.5
EBG-060	EBG113	0 to 0.5
EBG-060	EBG114	0 to 0.5
EBG-060	EBG115	0 to 0.5
EBG-061	EBG116	0 to 0.5
EBG-061	EBG118	0 to 0.5
EBG-062	EBG119	0 to 0.5
EBG-062	EBG121	0 to 0.5
EBG-063	EBG122	0 to 0.5
EBG-063	EBG124	0 to 0.5
EBG-064	EBG125	0 to 0.5

Table 6-4. Human Health Risk Assessment Data Set for Sediment Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)
EBG-064	EBG126	0 to 0.5
EBG-064	EBG127	0 to 0.5
EBG-065	EBG128	0 to 0.5
EBG-065	EBG130	0 to 0.5
EBG-066	EBG131	0 to 0.5
EBG-066	EBG133	0 to 0.5
EBG-067	EBG134	0 to 0.5
EBG-067	EBG136	0 to 0.5
EBG-068	EBG139	0 to 0.5
EBG-069	EBG140	0 to 0.5
EBG-069	EBG142	0 to 0.5
EBG-070	EBG143	0 to 0.5
EBG-070	EBG144	0 to 0.5
EBG-070	EBG145	0 to 0.5
EBG-071	EBG146	0 to 0.5
EBG-071	EBG148	0 to 0.5
EBG-072	EBG151	0 to 0.5
EBG-073	EBG154	0 to 0.5
EBG-074	EBG155	0 to 0.5
EBG-074	EBG157	0 to 0.5
EBG-075	EBG158	0 to 0.5
EBG-075	EBG160	0 to 0.5
EBG-076	EBG161	0 to 0.5
EBG-076	EBG163	0 to 0.5
EBG-077	EBG164	0 to 0.5
EBG-077	EBG166	0 to 0.5
EBG-078	EBG167	0 to 0.5
EBG-078	EBG169	0 to 0.5
EBG-079	EBG170	0 to 0.5
EBG-079	EBG171	0 to 0.5
EBG-079	EBG172	0 to 0.5
EBG-080	EBG173	0 to 0.5
EBG-081	EBG174	0 to 0.5
EBG-082	EBG175	0 to 0.5
EBG-083	EBG176	0 to 0.5
EBG-084	EBG177	0 to 0.5
EBG-085	EBG178	0 to 0.5
EBG-086	EBG179	0 to 0.5
EBG-087	EBG180	0 to 0.5
EBG-088	EBG181	0 to 0.5
EBG-089	EBG182	0 to 0.5
EBG-090	EBG183	0 to 0.5
EBG-091	EBG184	0 to 0.5
EBG-092	EBG185	0 to 0.5

Table 6-4. Human Health Risk Assessment Data Set for Sediment Erie Burning Grounds (continued)

Station	Sample ID	Depth (ft bgs)		
EBG-093	EBG186	0	to	0.5
EBG-094	EBG187	0	to	0.5
EBG-095	EBG188	0	to	0.5
EBG-096	EBG189	0	to	0.5
EBG-097	EBG190	0	to	0.5
EBG-098	EBG191	0	to	0.5
EBG-099	EBG192	0	to	0.5
EBG-100	EBG193	0	to	0.5
EBG-101	EBG194	0	to	0.5
EBG-102	EBG195	0	to	0.5
EBG-103	EBG196	0	to	0.5
EBG-104	EBG197	0	to	0.5
EBG-105	EBG198	0	to	0.5
EBG-106	EBG199	0	to	0.5
EBG-107	EBG200	0	to	0.5
EBG-108	EBG201	0	to	0.5
EBG-109	EBG202	0	to	0.5
EBG-110	EBG203	0	to	0.5
EBG-111	EBG204	0	to	0.5
EBG-112	EBG205	0	to	0.5
EBG-113	EBG206	0	to	0.5
EBG-114	EBG207	0	to	0.5
EBG-115	EBG208	0	to	0.5
EBG-116	EBG209	0	to	0.5
EBG-117	EBG210	0	to	0.5
EBG-118	EBG211	0	to	0.5
EBG-119	EBG212	0	to	0.5
EBG-120	EBG282	0	to	0.5
EBG-146	EBG306	0	to	0.5
EBG-147	EBG307	0	to	0.5
EBG-148	EBG308	0	to	0.5
EBG-149	EBG309	0	to	0.5
EBG-150	EBG310	0	to	0.5
EBG-151	EBG311	0	to	0.5

bgs = Below ground surface.

Table 6-5. Human Health Risk Assessment Data Set for Surface Water Erie Burning Grounds

Station	Sample ID
EBG-082	EBG219
EBG-086	EBG215
EBG-089	EBG220
EBG-091	EBG221
EBG-094	EBG222
EBG-097	EBG229
EBG-101	EBG213
EBG-107	EBG218
EBG-109	EBG214
EBG-110	EBG216
EBG-112	EBG223
EBG-113	EBG224
EBG-114	EBG225
EBG-115	EBG226
EBG-116	EBG227
EBG-117	EBG228
EBG-119	EBG230
EBG-120	EBG281
EBG-154	EBG318
EBG-155	EBG319
EBG-156	EBG320
EBG-157	EBG321
EBG-158	EBG322
EBG-159	EBG323
EBG-160	EBG324
EBG-161	EBG325

Table 6-6. Human Health Risk Assessment Data Set for Groundwater Erie Burning Ground

Station	Sample ID
EBGmw-123	EBG283
EBGmw-124	EBG284
EBGmw-125	EBG285
EBGmw-126	EBG286
EBGmw-127	EBG287
EBGmw-128	EBG288
EBGmw-129	EBG289
EBGmw-130	EBG290

- Surface soil is defined as soil from 0 to 1 ft bgs (shallow surface soil) for all receptors except the National Guard Trainee. Note that sampling efforts at EBG to date resulted in soil samples being collected at various depth intervals, including but not limited to, data from: (1) 0 to 1 ft bgs, and (2) 0 to 2 ft bgs. Because both of these intervals include soil within the 0 to 1-ft bgs interval, they are considered as surface soil and are evaluated as such in this HHRA. Surface soil is defined as 0 to 4 ft bgs (deep surface soil) for the National Guard Trainee; however, no samples are available below 3 ft bgs. Soil samples were taken to a maximum depth of 3 ft bgs because field screening did not identify any explosives in the samples collected. Soil data from both Phase I (1999) and Phase II (2003) sampling events are evaluated in this HHRA.

- Subsurface soil is defined as soil from 4 to 7 ft for the National Guard Trainee and 1 to 12 ft bgs for the Resident Subsistence Farmer. No samples are available below 3 ft bgs; therefore, subsurface soil is not evaluated for the National Guard Trainee. Subsurface soil samples collected from 1 to 3 ft bgs are evaluated for the Resident Subsistence Farmer.

- Sediment and surface water data from both Phase I (1999) and Phase II (2003) sampling events are evaluated in this HHRA to characterize risks from these media.

- Groundwater data from Phase II (2003) only are evaluated in this HHRA.

EBG encompasses approximately 35 acres and is evaluated as a single EU in this HHRA for groundwater, surface soil, sediment, and surface water. Evaluation as a single EU is appropriate for the potential current and future exposures at this site (i.e., restricted access with occasional use by waterfowl hunters or use by the National Guard to obtain water for fire/dust suppression; 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.

COPCs are identified for the one EU data set for groundwater, surface soil, sediment, and surface water. This data evaluation consists of five steps per the FWHHRAM (USACE 2004b): (1) a DQA, (2) frequency-of-detection/WOE screening, (3) screening of essential human nutrients, (4) risk-based screening, and (5) background screening.

1. **Data Quality Assessment** – Analytical results were reported by the laboratory in electronic form and loaded into an EBG 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 EBG 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 Data Quality Summary Report for the Phase I and II RIs (see Appendix G).

2. **Frequency-of-Detection/WOE Screen** – Each chemical in each medium was evaluated to determine its frequency of detection (see Section 4.1). Chemicals that were never detected for a given medium were eliminated as COPCs. For chemicals with at least 20 samples and a frequency of

detection of less than 5%, a WOE approach was used to determine if the chemical is AOC-related. The magnitudes and locations (clustering) of the detections and potential source of the chemical were evaluated. If the detected results showed no clustering, the concentrations are not substantially elevated relative to the detection limit, and the chemical was not used in the area under investigation, they are considered spurious, and the chemical was eliminated from further consideration. This screen is applied to all organic and inorganic chemicals with the exception of explosives and propellants. No detected explosives and propellants are excluded from the list of COPCs based on frequency of detection.

3. **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 1989a). 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 concentrations > 1,000,000 mg/kg). Receptors ingesting 100 mg of soil 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 per day would require groundwater 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, phosphorus, and sodium, respectively, to meet their RDA/RDI. Receptors ingesting 0.1 L of surface water per day would require concentrations of 10,000; 1.5; 100 to 180; 3,100 to 4,000; 35,000; 7,000; and 24,000 mg/L of calcium, iodine, iron, magnesium, potassium, phosphorus, and sodium, respectively, to meet their RDA/RDI. Concentrations of essential nutrients do not exceed these levels at EBG with the exception of iron in unfiltered surface water, which exceeds these levels in 1 of 26 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.

4. **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 each exposure medium is compared against 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.

5. **Background Screen** – For each inorganic constituent detected, concentrations in the EBG samples are screened against available, naturally occurring background levels. 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 soil and sediment, a conservative screen is performed using the most current residential preliminary remediation goals (PRGs) published by EPA Region 9 (EPA 2004b). 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.htm).

- Surface water and groundwater data are screened using the EPA Region 9 tap water PRGs, which are also available at http://www.epa.gov/region09/waste/sfund/prg/index.htm.

6.2.1.2 Background screening values

This EBG Phase II RI does not include determination of background data specific to EBG. Analytical results are screened against the final facility-wide background values for RVAAP, published in the Final Phase II RI Report for WBG (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 EBG are compared against the surface facility-wide soil background values.

6.2.1.3 COPC screening assumptions

The data set used to determine COPCs includes data collected from both Phase I and Phase II. 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 EBG.

- 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 was not analyzed for, (2) hexavalent chromium is more toxic than trivalent chromium (the only other valence of chromium with screening values), and (3) 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 summarized for each medium in Appendix N, Tables N-1 to N-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.

Table 6-7 summarizes the resulting COPCs across all media evaluated in this HHRA. COPCs are categorized as quantitative (based on available toxicity values, these chemicals are further evaluated

Table 6-7. COPCs for each Medium at Erie Burning Grounds

COPC	Groundwater	Surface Soil		Subsurface Soil	Sediment	Surface Water
		Shallow	Deep			
***Quantitative COPCs*[a]**						
Inorganics						
Aluminum		X	X	X	X	X
Antimony		X	X	X	X	X
Arsenic	X	X	X	X	X	X
Barium		X	X		X	
Cadmium		X	X		X	X
Chromium[b]		X	X	X	X	X
Copper		X	X		X	
Lead[c]	X	X	X		X	X
Manganese		X	X		X	X
Nickel					X	
Thallium			X	X		
Vanadium		X	X	X	X	X
Zinc		X	X		X	
Organics						
2,4,6-Trinitrotoluene		X	X	X	X	
Benz(*a*)anthracene		X	X			
Benzo(*a*)pyrene		X	X	X		
Benzo(*b*)fluoranthene		X	X		X	
Indeno(1,2,3-*cd*)pyrene		X	X			
Chloroform						X
***Qualitative COPCs*[d]**						
Organics						
2-Amino-4,6-dinitrotoluene		X	X			
4-Amino-2,6-dinitrotoluene		X	X			
Benzo(*g*,*h*,*i*)perylene		X	X			
Nitrocellulose		X	X	X	X	X
Phenanthrene		X	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.

quantitatively in this HHRA) and qualitative (due to a lack of toxicity values, risks and hazards cannot be quantified for these chemicals in this HHRA); see the Toxicity Assessment (Section 6.4) for more details on toxicity.

6.2.2.1 Groundwater COPCs

Table 6-7 summarizes the COPCs for groundwater. As seen, two metals are identified as groundwater COPCs at EBG: lead and arsenic.

6.2.2.2 Surface soil COPCs

Table 6-7 summarizes the COPCs for shallow (0 to 1 ft bgs) and deep (0 to 3 ft bgs) surface soil.

Shallow surface soil COPCs

A total of 21 shallow surface soil COPCs are identified at EBG. The 21 COPCs include:

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

- 4 explosives (2,4,6-TNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitrocellulose), and

- 6 SVOCs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*g*,*h*,*i*)perylene, indeno(1,2,3-*cd*)pyrene, and phenanthrene].

Based on lack of toxicity information (see Section 6.3), 5 of these 21 shallow surface soil COPCs are classified as qualitative COPCs [2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g*,*h*,*i*)perylene; and phenanthrene]; risks and hazards cannot be quantified for these 5 COPCs.

Deep surface soil COPCs

A total of 22 deep surface soil COPCs are identified at EBG. The 22 COPCs include

- 12 inorganics (aluminum, antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, thallium, vanadium, and zinc),

- 4 explosives (2,4,6-TNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitrocellulose), and

- 6 SVOCs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, benzo(*g*,*h*,*i*)perylene, indeno(1,2,3-*cd*)pyrene, and phenanthrene].

Based on lack of toxicity information (see Section 6.3), 5 of these 22 deep surface soil COPCs are classified as qualitative COPCs [2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g*,*h*,*i*)perylene; and phenanthrene]; risks and hazards cannot be quantified for these 5 COPCs.

6.2.2.3 Subsurface soil COPCs

Table 6-7 summarizes the COPCs for subsurface soil. A total of nine subsurface soil COPCs are identified at EBG. The nine COPCs include

- six inorganics (aluminum, antimony, arsenic, chromium, thallium, and vanadium),

- two explosives (2,4,6-TNT and nitrocellulose), and

- one SVOC [benzo(*a*)pyrene].

Based on lack of toxicity information (see Section 6.3), one of these nine subsurface soil COPCs is classified as a qualitative COPC (nitrocellulose); risks and hazards cannot be quantified for this COPC.

6.2.2.4 Sediment COPCs

As seen on Table 6-7, a total of 16 sediment COPCs are identified at EBG. The 16 COPCs include

- 12 inorganics (aluminum, antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, nickel, vanadium, and zinc),

- 2 explosives (2,4,6-TNT and nitrocellulose), and

- 2 SVOCs [benzo(*b*)fluoranthene and phenanthrene].

Based on lack of toxicity information (see Section 6.3), 2 of these 16 sediment COPCs are classified as qualitative COPCs (nitrocellulose and phenanthrene); risks and hazards cannot be quantified for these 2 COPCs.

6.2.2.5 Surface water COPCs

Table 6-7 summarizes the COPCs for surface water. As seen, a total of ten surface water COPCs are identified at EBG. The ten COPCs include

- eight inorganics (aluminum, antimony, arsenic, cadmium, chromium, lead, manganese, and vanadium),

- one explosive (nitrocellulose), and

- one VOC (chloroform).

Based on lack of toxicity information (see Section 6.3), one of these ten surface water COPCs is classified as a qualitative COPC (nitrocellulose); risks and hazards cannot be quantified for this COPC.

6.2.2.6 Summary of COPCs

Table 6-7 summarizes the resulting COPCs for groundwater, surface soil, subsurface soil, sediment, and surface water at EBG. As seen, a total of 24 COPCs are identified within the EBG aggregate. The 24 COPCs include

- 13 inorganics (aluminum, antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, nickel, thallium, vanadium, and zinc),

- 4 explosives (2,4,6-TNT; 2-amino-4,6-DNT; 4-amino-2,6-DNT; and nitrocellulose),

- 6 SVOCs [benz(*a*)anthracene, benzo(*a*)pyrene, benzo(b)fluoranthene, benzo(*g*,*h*,*i*)perylene, indeno(1,2,3-*cd*)pyrene, and phenanthrene], and

- 1 VOC (chloroform).

Based on lack of toxicity information (see Section 6.3), 5 of these 24 COPCs are classified as qualitative COPCs [2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g,h,i*)perylene; and phenanthrene]; risks and hazards cannot be quantified for these 5 COPCs.

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

EBG may contain MEC and contains environmentally sensitive areas (i.e., wetlands). As a result, this area is classified as Restricted Access. Current plans call for the site to remain Restricted Access in the future. Restricted access means this area will not be opened to general training, primarily because it is a wetland. EBG 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 here only after authorized personnel are properly briefed on potential hazards/sensitive areas. Individuals unfamiliar with the hazards/restrictions are escorted by authorized personnel at all times while in the restricted area (USACE 2004b).

6.3.2 Potentially Exposed Populations, Exposure Media, and Exposure Pathways

Potentially contaminated media at EBG are surface soil, subsurface soil, groundwater, surface water, and sediment.

Given the restricted access and wetland, EBG may be used in the future by two receptor populations:

- National Guard personnel using surface water for fire or dust suppression.
- Recreational users involved in waterfowl hunting.

These limited activities are compatible with protection of the wetland resource and safety concerns regarding MEC. Hunting is not currently allowed at EBG. Hunters are not allowed at areas that are restricted for environmental reasons (i.e., due to known contamination hazards or during the RI process). Hunting at RVAAP is also restricted for reasons other than environmental – including logistics, general safety, security, and military operations. Military and training site employees are occasionally allowed hunting access to some restricted areas under direct supervision of someone knowledgeable about the site and the security and safety issues associated with it. If hunting is allowed at EBG in the future, hunters will be restricted as they are anywhere at RVAAP. That is, hunters are told where they can and cannot hunt and volunteers are responsible for making sure hunters know the boundaries of their areas and for patrolling the perimeter of hunting areas. All hunters are briefed before they go into the field and told to stay within their assigned areas and to keep vehicles on the roads.

These two receptors (National Guard Fire/Dust Suppression Worker and Waterfowl Hunter) are evaluated as outlined in Table 5 of the FWHHRAM (USACE 2004). The National Guard Fire/Dust Suppression Worker is assumed to spend 4 hrs/day for 5 days/year for fire suppression and 4 hrs/day for 10 days/year (i.e., 40 hrs/year) for dust suppression, and is assumed to return to RVAAP and the AOC of interest every year for their entire 25-year enlistment. The hunter is assumed to be on-site 6 hrs/day for 2 days/year and is assumed to hunt at EBG every year that they live in the area (i.e., residential exposure duration of 30 years). Both of these receptors may be exposed to shallow surface soil (0 to 1 ft bgs), surface water, and sediment. Subsurface soil is not evaluated for these receptors because they are not engaged in intrusive activities and are not exposed to this medium, per Tables 1 and 5 of the FWHHRAM (USACE 2004b). Groundwater use is not a completed exposure pathway for these two receptors.

EBG is not currently included in the RVAAP catch and release program. The fishery at EBG is very limited because the wetland is so shallow. According to the OHARNG – RTLS, EBG will never be a good fishing pond. It is, however, a very good waterfowl habitat and waterfowl hunting area (Morgan 2004). Thus, because of the surface water habitat characteristics (i.e., shallow with lots of aquatic vegetation), the waterfowl hunter is evaluated in this HHRA, but the fisherman is not.

Exposures to contaminants in shallow surface soil, surface water, and sediment at EBG are evaluated for incidental ingestion, dermal contact, and inhalation by a National Guard Fire/Dust Suppression Worker and Recreational Hunter/Trapper, and ingestion of waterfowl by the Recreational Hunter/Trapper as defined in Tables 1 and 5 of the FWHHRAM (USACE 2004b).

Future sampling of environmental media (e.g., groundwater) may occur at EBG. Exposure by sampling personnel is not evaluated in this HHRA because workers engaged in environmental sampling are expected to wear proper personal protective equipment, including gloves, and to follow health and safety protocols (e.g., no eating or smoking) to minimize/prevent incidental exposure.

In addition to the representative receptors described above, the other three receptors described in the FWHHRAM [National Guard Trainee, Security Guard/Maintenance Worker, 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 EBG due to physical constraints and intended future land use by OHARNG. Exposures to the National Guard Trainee are not anticipated due to physical constraints (e.g., wetlands and MEC) and the OHARNG land use plan, which does not include training in this area. 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 surface soil, sediment, and surface water

This HHRA for EBG 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 in groundwater, surface soil, subsurface soil, sediment, and surface water are calculated using equations from EPA guidance, *Supplemental Guidance to RAGS: Calculating the Concentration Term*

(EPA 1992a). 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 EBG, 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:

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

where

$\overline{x}_n$ = 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 2002c) 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 EBG 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:

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

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 2002c) 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, subsurface soil, sediment, and surface water are provided in Appendix N, Tables N-1 through N-6.

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 above. Other parameter values are provided in Table 6-8.

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:

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

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:

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

where

R_{upp} = multiplier for dry root uptake for pasture (unitless),
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 $2.5 \times 10^{-8} \times K_{ow.}$ No VOCs were identified as COPCs in soil at EBG.

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a]

		Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker**	**Dust/Fire Control[b]**	**Trainee**	**Hunter/ Fisher[b, c]**	**Adult**	**Child**
Surface Soil[d]							
Incidental Ingestion							
Soil ingestion rate	kg/d	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Exposure time	hr/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/hr	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 N-7					
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	$(kg\text{-}cm^2)/(mg\text{-}m^2)$	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	hr/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/hr	0.042	0.042	0.042	0.042	0.042	0.042

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a] (continued)

Exposure Pathway and Parameter	Units	Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
		Security Guard/ Maintenance Worker	Dust/Fire Control[b]	Trainee	Hunter/ Fisher[b, c]	Adult	Child
Subsurface Soil							
Incidental Ingestion							
Soil ingestion rate	kg/d	NA	NA	NA	NA	0.0001	0.0002
Exposure time	hr/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/hr	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 N-7	
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	hr/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
Conversion factor	d/hr	NA	NA	NA	NA	0.042	0.042

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a] (continued)

Exposure Pathway and Parameter	Units	Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
		Security Guard/ Maintenance Worker	Dust/Fire Control[b]	Trainee	Hunter/ Fisher[b, c]	Adult	Child
Sediment							
Incidental Ingestion							
Soil ingestion rate	kg/d	NA	0.0001	0.0001	0.0001	0.0001	0.0002
Exposure time	hr/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/hr	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	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 N-7				
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	20	10
Exposure time	hr/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/hr	NA	0.042	0.042	0.042	0.042	0.042
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

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a] (continued)

Exposure Pathway and Parameter	**Units**	**Potential Receptor**					
		National Guard Personnel				**Resident Subsistence Farmer**	
		Security Guard/ Maintenance Worker	**Dust/Fire Control[b]**	**Trainee**	**Hunter/ Fisher[b, c]**	**Adult**	**Child**
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	hr/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	hr/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
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
Foodstuffs							
Ingestion of Waterfowl							
Waterfowl ingestion rate	kg/d	NA	NA	NA	0.0132	NA	NA
Fraction ingested	unitless	NA	NA	NA	1	NA	NA

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a] (continued)

Exposure Pathway and Parameter	Units	Potential Receptor					
		National Guard Personnel				Resident Subsistence Farmer	
		Security Guard/ Maintenance Worker	Dust/Fire Control[b]	Trainee	Hunter/ Fisher[b, c]	Adult	Child
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
Fraction browse ingested from site	unitless	NA	NA	NA	NA	0.08[h]	0.08[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
Non-carcinogen 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
Non-carcinogen 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

Table 6-8. Parameters Used to Quantify Exposures for Each Medium and Receptor at Erie Burning Grounds[a] (continued)

		Potential Receptor					
		National Guard Personnel				**Resident Subsistence Farmer**	
Exposure Pathway and Parameter	**Units**	**Security Guard/ Maintenance Worker**	**Dust/Fire Control[b]**	**Trainee**	**Hunter/ Fisher[b, c]**	**Adult**	**Child**
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
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
Non-carcinogen 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
Non-carcinogen 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] Fire/Dust Suppression Worker and Hunter/Trapper are representative receptors at the Erie Burning Grounds (EBG).

[c] EBG is not a fishery because it is too shallow; therefore, the Hunter/Fisher receptor is evaluated as a Hunter only.

[d] Surface soil is defined as 0 to 1 ft below ground surface (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 EBG, samples were collected to a maximum depth of 3 ft bgs.

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

f[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.

NA = Not applicable for this scenario.

VOC = Volatile organic compound.

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:

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

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 $7.5 \times 10^{-9} \times K_{ow.}$ No VOCs were identified as COPCs in soil at EBG.

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:

$$C_{p\,=}\,(CF)(C_s)(\,B_p) \tag{6-7}$$

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:

$$\log B_p = 1.588 - 0.578 \log K_{ow} \tag{6-8}$$

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).

No VOCs were identified as COPCs in soil at EBG.

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 34.6-acre EBG AOC is 0.08 (14 ha/175 ha) based on a 175-ha 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).

No VOCs were identified as COPCs in soil at EBG.

6.3.3.3 EPCs in wildfowl

The determination of EPCs in wildfowl/waterfowl is described in detail in Appendix N, Section N3. EPCs for wildfowl are found in Table N-32. These EPCs are calculated assuming waterfowl are exposed continuously to contaminants at EBG 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 EBG; therefore, while at RVAAP, waterfowl spend only a portion of their time at EBG.

6.3.4 Exposure Parameters and Calculations for Estimating Intakes

Standard intake equations from EPA guidance (EPA 1989a) for ingestion, dermal contact, and inhalation of chemicals in water and soil/sediment (shown below) are used along with the exposure parameters shown in Table 6-8. Exposure parameters and intake equations are from the FWHHRAM (USACE 2004b).

6.3.4.1 Surface soil and sediment exposure pathways

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

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

where

C_s = chemical concentration in soil or sediment (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 or sediment is calculated using Equation 6-13.

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

where

C_s = chemical concentration in soil or sediment (mg/kg),
CF = conversion factor [(10^{-6} kg/mg) × (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 dermal absorption factor (unitless; see Table N-7),
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 or sediment is calculated using Equation 6-14:

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

where

C_s = chemical concentration in soil or sediment (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 N-7),
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 particulate emission factor (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:

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

6.3.4.2 Surface water and groundwater exposure pathways

Ingestion of surface water and groundwater is estimated using Equation 6-15:

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

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:

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

where

C_w = chemical concentration in surface water (mg/L),
CF = conversion factor [(m/100 cm) × (1,000 L/m^3)],
PC = chemical-specific permeability constant (cm/h; see Table N-7),
SA = skin surface area exposed to surface water (m^2),
ET = exposure time (hr/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 is not evaluated for groundwater because no volatile COPCs have been identified in groundwater (see Section 6.2.2.1).Inhalation of VOCs from surface water is not quantified because only 1 volatile COPC (chloroform) was identified, with concentrations detected in 3 of 26 surface water samples (see Section 6.2.2.5).

6.3.4.3 Ingestion of food pathway

Ingestion of foodstuffs (wildfowl, beef, milk, vegetables, and venison) is estimated using Equation 6-17:

$$Chemical\ Intake\ (mg/kg\text{-}\ day) = \frac{C\,fowl \times IR\,fowl \times EF \times ED \times FI}{BW \times AT}\ , \qquad \textbf{(6-17)}$$

where

C_{fowl} = chemical-specific concentration in food product (mg/kg),
IR_{fowl} = 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 EBG.

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 apply 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 exposure media at EBG are listed in Table N-8 (EPA 1997b, 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 m^3/d)/70 kg = RfD] (EPA 1989a).

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 1989a). Since the potential receptors at EBG 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 1989a).

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 N-9 (EPA 1997b, 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 2002a):

$$RfD_{dermal} = RfD_{oral} \times GAF \qquad \textbf{(6-18)}$$

$$CSF_{dermal} = CSF_{oral}/GAF \qquad \textbf{(6-19)}$$

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 N-8 and N-9.

6.4.4 Assumptions Used in the Toxicity Assessment

Assumptions made in assigning toxicity values for COPCs at EBG are as follows:

- 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 EBG to an equivalent concentration of benzo(*a*)pyrene.

cPAH	**TEF**
Benzo(*a*)pyrene	1
Benz(*a*)anthracene	0.1
Benzo(*b*)fluoranthene	0.1
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 EBG 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 EBG, their effects cannot be quantified at the present time. COPCs without RfDs and CSFs are 2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g*,*h*,*i*)perylene; and phenanthrene.

No RfDs or CSFs are available for lead, which is a COPC for groundwater, surface soil, sediment, and surface water (see Table 6-7). EPA (1999a) 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 N, Tables N-10 through N-12. 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/Trapper 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 7) 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 Pb 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 N, Table N-12.

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 EBG.

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 1990b). 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 1989a):

$$ILCR = I \times CSF \qquad \textbf{(6-20)}$$

where

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

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 6-21 below:

$$ILCR_{total} = \Sigma ILCR_i \qquad \textbf{(6-21)}$$

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 (1989a) 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 Fire/Dust Suppression Worker present at EBG can reasonably be assumed to both ingest surface soil and inhale contaminated dust from the same area.

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 1989a) and is calculated as:

$$HQ = I/RfD \tag{6-22}$$

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:

$$HI = \Sigma HQ_i \tag{6-23}$$

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 1989a). 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 chemicals of concern

Risks are characterized for each exposure medium/receptor combination. COCs are identified if the total ILCR for a chemical exceeds 10^{-6} or if total HIs exceed 1 for a medium/receptor combination.

6.5.2 Results

Estimated risks for EBG are evaluated for the Hunter/Trapper and Fire/Dust Suppression Worker as representative receptors exposed to shallow surface soil, sediment, and surface water. Shallow surface soil data are defined as coming from 0 to 1 ft bgs. Risks are also calculated for three additional receptors [National Guard Trainee, Security Guard/Maintenance Worker, 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 N-13 through N-27 for all exposure media for all five receptors evaluated. Results are summarized in the following sections for the representative receptors (Hunter/Trapper and Fire/Dust Suppression 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 results

Surface Soil – Direct Contact

Detailed hazard and risk results for all five receptors direct contact with COPCs in surface soil are presented in Tables N-13 and N-14 (shallow surface soil) and N-16 and N-17 (deep surface soil). 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 representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker) and Resident Subsistence Farmer direct contact with COPCs in surface soil are summarized in Table 6-9.

Table 6-9. Summary of Surface Soil Risks and Hazards for Direct Contact at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Fire/Dust Suppression Worker	0.0027	None	2.5E-07	None
Hunter/Trapper	0.00052	None	6.3E-08	None
Resident Subsistence Farmer (adult)	0.24	None	2.3E-05	Arsenic Benzo(*a*)pyrene
Resident Subsistence Farmer (child)	1.5	None	2.3E-05	Arsenic Benzo(*a*)pyrene

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

As seen, the total HI is 0.00052 for the Hunter/Trapper and 0.0027 for the Fire/Dust Suppression Worker. Thus, the HIs are below the threshold of 1.0 and no non-carcinogenic surface soil COCs are identified at EBG for these receptors.

The total cancer risk across all surface soil COPCs is 6.3E-08 and 2.5E-07 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Because the total cancer risk is below the threshold of 1.0E-06, no carcinogenic COCs are identified for surface soil at EBG for these receptors.

The total HIs for the Resident Subsistence Farmer Adult and Child are 0.24 and 1.5, respectively. No individual COPCs have HQs > 1. The highest individual HQ is 0.49 for arsenic exposure by the child. Thus, no non-carcinogenic surface soil COCs are identified at EBG for the Resident Subsistence Farmer.

The total cancer risk for the Resident Subsistence Farmer is 2.3E-05 for both the Adult and Child. Two COCs [arsenic and benzo(*a*)pyrene] are identified for this receptor. Arsenic has an estimated ILCR in excess of Ohio EPA's level of concern of 1.0E-05 for this receptor. Note that the EPC for arsenic is 11 mg/kg, which is below the arsenic background soil concentration of 15.4 mg/kg. Thus, the cancer risk related to arsenic at EBG 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 N-17 and N-18 and summarized in Table 6-10. Indirect contact includes ingestion of venison, beef, milk, and vegetables. The Resident Subsistence Farmer is the only receptor potentially exposed by these indirect pathways.

Table 6-10. Summary of Surface Soil Risks and Hazards for Ingestion of Foodstuffs at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (adult)	34	Aluminum, Antimony, Arsenic, Barium, Chromium, Copper, Manganese, Zinc	2.9E-03	Arsenic, 2,4,6-TNT Benzo(*a*)anthracene, Benzo(*a*)pyrene, Benzo(*b*)fluoranthene, Indeno(*1,2,3-cd*)pyrene
Resident Subsistence Farmer (child)	160	Aluminum, Antimony, Arsenic, Barium, Cadmium, Chromium, Copper, Manganese, Vanadium, Zinc, 2,4,6-TNT	2.8E-03	Arsenic, 2,4,6-TNT Benzo(*a*)anthracene, Benzo(*a*)pyrene, Benzo(*b*)fluoranthene, Indeno(*1,2,3-cd*)pyrene

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

The total HIs for the Resident Subsistence Farmer Adult and Child exposed to surface soil COPCs via ingestion of foodstuffs are 34 and 160, respectively. Eleven non-carcinogenic surface soil COCs are identified at EBG 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 2.9E-03 and 2.8E-03, respectively, coming predominantly from PAHs. Six carcinogenic surface soil COCs are identified.

These hazards and 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 EBG. Lead model results for the Security Guard/Maintenance Worker, and Resident Subsistence Farmer (adult and child) are provided in Appendix N Tables N-10 through N-12. For the Resident Subsistence Farmer Adult, the estimated probability of fetal PbB concentrations exceeding acceptable levels ranged from 1.2 to 2.1% at EBG (see Table N-11). For the Resident Subsistence Farmer Child, the estimated probability of PbB concentrations exceeding acceptable levels is 5.4% at EBG (see Table N-12).

6.5.2.2 Subsurface soil results

Detailed hazard and risk results for all Resident Subsistence Farmer (adult and child) direct contact with COPCs in subsurface soil are presented in Tables N-19 and N-20. Direct contact includes incidental ingestion of soil, inhalation of VOCs and particulates (i.e., dust) from soil, and dermal contact with soil. The Resident Subsistence Farmer is the only receptor exposed to subsurface soil. Hazard and risk results for the Resident Subsistence Farmer are summarized in Table 6-11.

Table 6-11. Summary of Subsurface Soil Risks and Hazards for Direct Contact at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (adult)	0.14	None	1.5E-05	Arsenic Benzo(*a*)pyrene
Resident Subsistence Farmer (child)	0.88	None	1.7E-05	Arsenic

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

The total HIs for the Resident Subsistence Farmer Adult and Child are 0.14 and 0.88, respectively. Thus, the HIs are below the threshold of 1.0 and no non-carcinogenic surface soil COCs are identified at EBG for the Resident Subsistence Farmer.

The total cancer risks for the Resident Subsistence Farmer Adult and Child are 1.5E-05 and 1.7E-05, respectively. Two COCs [arsenic and benzo(*a*)pyrene] are identified for this receptor. Arsenic has an estimated ILCR in excess of Ohio EPA's level of concern of 1.0E-05 for this receptor. Note that the EPC for arsenic is 9.3 mg/kg, which is below the arsenic background soil concentration of 15.4 mg/kg. Thus, the cancer risk related to arsenic at EBG does not exceed the cancer risk for arsenic estimated from the facility-wide background.

6.5.2.3 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 N-21 and N-22. The representative receptors at EBG are not exposed to groundwater. Hazard and risk results for the

Resident Subsistence Farmer direct contact with COPCs in groundwater are summarized in Table 6-12. 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 6-12. Summary of Groundwater Risks and Hazards at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Resident Subsistence Farmer (adult)	2.6	Arsenic	5.1E-04	Arsenic
Resident Subsistence Farmer (child)	9.2	Arsenic	3.5E-04	Arsenic

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

One groundwater COC (arsenic) is identified for the Resident Subsistence Farmer.

6.5.2.4 Sediment results

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/Trapper) direct contact with COPCs in sediment are presented in Tables N-23 and N-24. Direct contact includes incidental ingestion of sediment, inhalation of VOCs and particulates (i.e., dust) from sediment, and dermal contact with sediment. Hazard and risk results for the representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker) and Resident Subsistence Farmer direct contact with COPCs in sediment are summarized in Table 6-13.

Table 6-13. Summary of Sediment Risks and Hazards for Direct Contact at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Fire/Dust Suppression Worker	0.0085	None	2.2E-07	None
Hunter/Trapper	0.0017	None	5.5E-08	None
Resident Subsistence Farmer (adult)	0.88	None	2.2E-05	Arsenic Benzo(*b*)fluoranthene
Resident Subsistence Farmer (child)	6.6	Antimony	2.5E-05	Arsenic

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

As seen, the total HI is 0.0017 for the Hunter/Trapper and 0.0084 for the Fire/Dust Suppression Worker. Because the HIs are below the threshold of 1.0, no non-carcinogenic COCs are identified for sediment at EBG for these receptors.

The total cancer risk across all sediment COPCs is 5.5E-08 and 2.2E-07 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Because the total cancer risk is below the threshold of 1.0E-06, no carcinogenic COCs are identified for sediment at EBG.

The total HIs are 0.88 and 6.6 for Resident Subsistence Farmer Adult and Child, respectively. The total cancer risks are 2.2E-05 (adult) and 2.5E-05 (child). Three sediment COCs [antimony, arsenic, and benzo(*b*)fluoranthene] are identified for the Resident Subsistence Farmer.

6.5.2.5 Surface water results

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/Trapper) direct contact with COPCs in surface water are presented in Tables N-25 and N-26. Direct contact includes incidental ingestion of surface water and dermal contact with surface water. Hazard and risk results for the representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker) and Resident Subsistence Farmer direct contact with COPCs in surface water are summarized in Table 6-14.

Table 6-14. Summary of Surface Water Risks and Hazards for Direct Contact at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Fire/Dust Suppression Worker	0.098	None	2.9E-06	Arsenic
Hunter/Trapper	0.023	None	4.0E-07	None
Resident Subsistence Farmer (adult)	2.4	Manganese	8.1E-05	Arsenic
Resident Subsistence Farmer (child)	6.5	Arsenic, Manganese	6.6E-05	Arsenic

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

As seen, the total HI is 0.024 for the Hunter/Trapper and 0.098 for the Fire/Dust Suppression Worker. Because the HIs are below the threshold of 1.0, no non-carcinogenic COCs are identified for surface water at EBG for these receptors.

The total cancer risk across all surface water COPCs is 4.0E-07 for the Hunter/Trapper and 2.9E-06 for the Fire/Dust Suppression Worker. Because the total cancer risk for the Hunter/Trapper is below the threshold of 1.0E-06, no carcinogenic COCs are identified for surface water at EBG for this receptor. Arsenic, with total risk of 2.9E-06, is identified as the lone surface water COC for the Fire/Dust Suppression Worker at EBG.

The total HIs are 2.4 and 6.5 for Resident Subsistence Farmer Adult and Child, respectively. The total cancer risks are 8.1E-05 (adult) and 6.6E-05 (child). Two surface water COCs (arsenic and manganese) are identified for the Resident Subsistence Farmer.

6.5.2.6 Waterfowl results

Detailed hazard and risk results for the Hunter/Trapper's ingestion of waterfowl for all COPCs in sediment and surface water are presented in Table N-27; these hazards and risks are summarized in Table 6-15.

As seen, the total HI is 7.1 for the Hunter/Trapper. Two metals are identified as non-carcinogenic COCs for the ingestion of waterfowl pathway at EBG: antimony and zinc.

Table 6-15. Summary of Risks and Hazards from Ingesting Waterfowl at Erie Burning Grounds

Receptor	Total HI	Non-carcinogenic COCs	Total ILCR	Carcinogenic COCs
Recreational Hunter/Trapper	7.1	Antimony	2.5E-04	Arsenic
		Zinc		Benzo(*b*)fluoranthene

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

The total cancer risk for the ingestion of wildfowl pathway is 2.5E-04 for the Hunter/Trapper. Because the total cancer risk for the Hunter/Trapper is well above the threshold of 1.0E-06, carcinogenic COCs are identified for the ingestion of wildfowl pathway at EBG for this receptor. Arsenic and benzo(*b*)fluoranthene, each with risk greater than 1.0E-04, are identified as COCs for the Hunter/Trapper eating the wildfowl at EBG.

The calculated risk from ingestion of arsenic in wildfowl tissue results primarily from the predicted bioaccumulation of arsenic from sediment to sediment/benthic invertebrates and subsequent ingestion and bioaccumulation by wildfowl. The EPC of arsenic in sediment (14 mg/kg) results in a predicted risk to a hunter from ingestion of wildfowl of 1.5E-04. The background concentration for arsenic (19.5 mg/kg) results in a predicted risk to a hunter from ingestion of wildfowl of 2.1E-04.

The calculated risk from ingestion of benzo(*b*)fluoranthene in wildfowl tissue also results primarily from the predicted bioaccumulation of benzo(*b*)fluoranthene from sediment to sediment invertebrates and subsequent ingestion and bioaccumulation by wildfowl. Benzo(*b*)fluoranthene was detected in only 9 of 92 sediment samples.

The calculation of risks for waterfowl ingestion is highly uncertain. One source of uncertainty is that waterfowl tissue concentrations are calculated assuming waterfowl are exposed continuously to contaminants at EBG only. This assumption is extremely 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 EBG; therefore, while at RVAAP, waterfowl spend only a portion of their time at EBG.

Likely residence times at ponds in Northeastern Ohio also vary from species to species. Mallards spend an average of 3 months (Ohio DNR 2005). Wood ducks and Canada geese spend much more time than mallards in the area with an average of 10 months. These residence times would result in temporal use factors (TUFs) ranging from 0.24 to 0.83.

The home ranges of waterfowl vary from species to species. For mallards, it averages 274 acres for laying ducks and 1,156 acres for ducks during various activities (EPA 1993). For wood ducks, the average home range for breeding males is 499 acres (California DFG 2005). For Canada geese, the average home range is 2,429 acres (EPA 1993). The EBG AOC is approximately 35 acres, with approximately 2.6 of these acres covered by surface water. These home ranges would result in area use factors (AUFs) ranging from 0.0011 to 0.009 for the aquatic portion of EBG.

The total HI would range from 0.0040 to 0.031 with the application of these AUFs and TUFs (reduced from 7.1). The ILCR for arsenic would range from 9.0E-08 to 6.9E-07 with the application of these TUFs and AUFs (reduced from 1.6E-04). The ILCR for benzo(*b*)fluoranthene would range from 5.6E-08 to 4.3E-07 with the application of these TUFs and AUFs (reduced from 1.0E-04). These revised risk estimates are also highly uncertain because they are based on assumptions that the entire 2.6-aquatic acres of EBG are uniformly contaminated and that bioaccumulation factors (BAFs) calculated for beef apply to waterfowl.

Note that the EPC for arsenic in sediment (14 mg/kg) is below its background concentration (19.5 mg/kg). Also note that benzo(*b*)fluoranthene is detected in less than 10% of the sediment samples (its frequency of detection is 9/92).

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 overestimation 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 EBG. 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).

Note that for the dermal contact with soil and sediment 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 or sediment in contact with the skin surface) for 24 hr following the initial exposure; therefore, the receptor is actually exposed to soil and sediment 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.

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.

A great deal of uncertainty in the exposure assessment is associated with the prediction of contaminant concentrations in waterfowl and subsequent exposures to hunters ingesting waterfowl tissue. Predicted risks are for a hypothetical duck that lives its life within EBG, getting all of its food from the aquatic portion of EBG, and is harvested by a hunter there. In reality, if hunters are allowed at EBG, the ducks harvested will come from a larger area. Wildfowl harvested at EBG would be exposed to surface water and sediment in a large area around EBG (i.e., its home range is larger than EBG) while in northeast Ohio and would be exposed to surface water and sediment across a multi-state area during migration and at wintering grounds in the southeastern United States.

Published data on whole-body tissue concentrations for ducks are not available – published data are for organs – so it is difficult to compare estimated duck tissue concentrations to published measurement data. Duck BAFs are not for specific organs. Duck-tissue concentrations of metals (e.g., antimony, arsenic, lead, and zinc) may be overestimated due to the use of conservative sediment-to-sediment invertebrate BAFs, duck biouptake factors, and duck diet (50% sediment invertebrate, 50% plant). In fact, the calculated concentration of lead in duck tissue (2.3 mg/kg) is comparable to the concentrations of lead in the liver and kidney of ducks with lead poisoning (Guitart et al. 1994). Comparisons of other COPCs are fraught with similar limitations. The predicted values are assumed to be conservative.

While a land use plan has been drafted for the RTLS, 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). To address this uncertainty, additional receptors (e.g., National Guard Trainee) 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 1989a).

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 EBG are Group A carcinogens (arsenic and hexavalent chromium), six are Group B carcinogens [cadmium, benz(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, chloroform, 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 multi-stage 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 1997b). 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 2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g,h,i*)perylene; 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 1989a). 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 five COPCs [2-amino-4,6-DNT; 4-amino-2,6-DNT; nitrocellulose; benzo(*g,h,i*)perylene; 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.

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. BAFs for PAHs for fish and crustaceans have been reported in the range of 10 to 10,000. Compounds with bioconcentration factors (BCFs) 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 to 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 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 are 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, arsenic was identified as a COC in shallow surface soil for a Resident Subsistence Farmer but not for either of the representative receptors (Fire/Dust Suppression Worker and Hunter/Trapper); however, shallow surface soil RGOs are calculated for arsenic for all five receptors exposed to shallow surface soil. RGOs are calculated for direct contact COCs only because the model used to estimate risk from waterfowl ingestion is extremely conservative and is not appropriate for calculating RGOs because it does not account for exposures to clean or contaminated media outside EBG and RVAAP as described previously. RGOs are calculated using the methodology presented in RAGS Part B (EPA 1991a) while incorporating site-specific exposure parameters applicable to EBG. RGOs are risk-based concentrations that may be considered in an FS to define the extent of contamination that must be remediated and to 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 Fire/Dust Suppression Worker is the concentration of arsenic that produces a risk of 10^{-5} when using the exposure parameters specific to the Fire/Dust Suppression Worker receptor.

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

$$\text{Risk} = (\text{Intake}) \times (\text{CSF}) \qquad \textbf{(6-24)}$$

and

$$\text{Hazard} = (\text{Intake}) / (\text{RfD}). \qquad \textbf{(6-25)}$$

The pathway-specific (e.g., incidental ingestion of water) 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 for the incidental ingestion of surface water pathway, note that by using the ingestion intake equation from Section 6.3.4.2 (Equation 6-15) and the general risk equation from Section 6.5.1, the risk from ingestion of surface water is calculated as

$$\text{Risk}_{\text{ing(water)}} = (C_w \times IR_w \times EF \times ED \times CSF) / (BW \times AT). \qquad \textbf{(6-26)}$$

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

$$\text{RGO}_{\text{ing(water)}} \text{ at } 10^{-5} = (10^{-5} \times BW \times AT) / (IR_w \times EF \times ED \times CSF). \qquad \textbf{(6-27)}$$

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:

$$\text{RGO}_{\text{ing(water)}} \text{ at } 1.0 = (1.0 \times BW \times AT \times RfD) / (IR_w \times EF \times ED). \qquad \textbf{(6-28)}$$

Thus, to obtain the ingestion of surface water RGO at the 10^{-5} risk level for the Fire/Dust Suppression Worker exposed to arsenic, the parameter values for the Fire/Dust Suppression Worker (from Table 6-8) and the chemical-specific oral CSF (from Table N-9) for arsenic are used:

$$RGO_{ing(water)} \text{ at } 10^{-5} \text{ for arsenic} = [(10^{-5})(70)(25550)] / (0.1)(15)(25)(1.5)] = 0.318 \text{ mg/L.}$$

In this example, the RGO calculated is 0.318 mg/L, which will produce a surface water ingestion risk of 10^{-5} for the Fire/Dust Suppression Worker exposed to arsenic in the surface water. This example is based on the ingestion of surface water; however, RGOs calculated for EBG 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. The representative receptors at EBG are the Fire/Dust Suppression Worker and Hunter/Trapper. Only one COC (arsenic in surface water) is identified for the Fire/Dust Suppression Worker, while no COCs are identified for the Hunter/Trapper; therefore, no downward adjustment of the TR and THI is required. A total of six COCs are identified for all media and all receptors combined [four carcinogens – arsenic, chromium, benzo(*a*)pyrene, and benzo(*b*)fluoranthene; and four non-carcinogens – antimony, arsenic, chromium, and manganese]; therefore, no downward adjustment of the TR and THI is required for any of the media or receptors evaluated.

RGOs for shallow surface soil, deep surface soil, subsurface soil, groundwater, sediment, and surface water are provided in Tables 6-16 through 6-21.

For the representative receptors (Fire/Dust Suppression Worker and Hunter/Trapper), it is noted that all surface water arsenic concentrations at EBG (the range of concentrations is from 0.00077 to 0.12 mg/L; see Table N-6) are smaller than the most conservative (i.e., smallest) RGO across all pathways (the surface water RGO based on a TR of 10^{-5} for the Fire/Dust Suppression Worker is 0.25 mg/L; see Table 6-21).

Table 6-16. RGOs for Shallow Surface Soil COCs at Erie Burning Grounds

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/Trapper								
Arsenic	1.5E+05	7.9E+03	8.2E+04	4.2E+03	--	1.0E+06	5.3E+04	2.8E+03
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
Benzo(*a*)pyrene	--	3.9E+02	--	5.1E+01	--	1.0E+06	--	4.5E+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
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
Benzo(*a*)pyrene	--	1.3E+00	--	4.4E+00	--	5.4E+04	--	9.7E-01
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
Benzo(*a*)pyrene	--	9.4E+01	--	1.3E+00	--	1.0E+06	--	1.3E+00

[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 6-17. RGOs for Deep Surface Soil COCs at Erie Burning Grounds

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	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	--

[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 6-18. RGOs for Subsurface Soil COCs at Erie Burning Grounds

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
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
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.
HI = Hazard index.
HQ = Hazard quotient.
RGO = Remedial goal option.
-- = No RGO could be quantified based on lack of approved toxicity value.

Table 6-19. RGOs for Groundwater COCs at Erie Burning Grounds

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	N/A	N/A	9.8E-02	6.1E-03
Resident Farmer Adult								
Arsenic	1.1E-02	5.7E-04	2.3E+00	1.2E-01	N/A	N/A	1.1E-02	5.7E-04
Resident Farmer Child								
Arsenic	3.1E-03	8.1E-04	1.1E+00	2.9E-01	N/A	N/A	3.1E-03	8.1E-04

[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.

Table 6-20. RGOs for Sediment COCs at Erie Burning Grounds

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/Trapper								
Antimony	2.0E+05	--	4.9E+05	--	--	--	1.4E+05	--
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(*b*)fluoranthene	--	1.6E+04	--	2.0E+03	--	1.0E+06	--	1.8E+03
National Guard Fire Suppression Worker								
Antimony	4.1E+04	--	1.0E+05	--	--	--	2.9E+04	--
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(*b*)fluoranthene	--	3.9E+03	--	5.1E+02	--	1.0E+06	--	4.5E+02
National Guard Trainee								
Antimony	2.6E+03	--	4.0E+04	--	--	--	2.5E+03	--
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(*b*)fluoranthene	--	2.5E+02	--	2.0E+02	--	2.2E+03	--	1.0E+02
Resident Farmer Adult								
Antimony	2.9E+02	--	1.9E+03	--	--	--	2.5E+02	--
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(*b*)fluoranthene	--	2.3E+01	--	7.9E+00	--	2.5E+05	--	5.9E+00
Resident Farmer Child								
Antimony	3.1E+01	--	2.1E+03	--	--	--	3.1E+01	--
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(*b*)fluoranthene	--	1.3E+01	--	4.4E+01	--	5.4E+05	--	9.7E+00

[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 6-21. RGOs for Surface Water COCs at Erie Burning Grounds

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/Trapper								
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	--
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	--
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	--
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	--
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	--

[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 EBG AOC at RVAAP. Risks and hazards were estimated for two representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker) exposed to three media (shallow surface soil, from a depth interval of 0 to 1 ft bgs; sediment; and surface water). Risks and hazards were also calculated for potential exposure to shallow or deep surface soil, groundwater, sediment, and surface water by three additional receptors [National Guard Trainee, Security Guard/Maintenance Worker, and Resident Subsistence Farmer (adult and child)]. The following steps were used to generate conclusions regarding human health risks and hazards associated with contaminated media at EBG:

- identification of COPCs,
- calculation of risks and hazards,
- identification of COCs, and
- calculation of RGOs.

Results are presented for all exposure scenarios, pathways, and media in Appendix N. Risk characterization results are summarized in Table 6-22 for all receptors.

Table 6-22. Summary of Human Health Risks and Hazards for Erie Burning Grounds

Receptor	Total HI	Total ILCR
Groundwater		
National Guard Trainee	0.29	4.7E-05
Resident Subsistence Farmer (adult)	2.6	5.1E-04
Resident Subsistence Farmer (child)	9.2	3.5E-04
Surface Soil[a]		
Fire/Dust Suppression Worker	0.0027	2.5E-07
Hunter/Trapper	0.00052	6.3E-08
National Guard Trainee	2.2	1.6E-05
Security Guard/Maintenance Worker	0.057	7.5E-06
Resident Subsistence Farmer (adult)	0.24	2.3E-05
Resident Subsistence Farmer (child)	1.5	2.3E-05
Agricultural Foodstuffs[b]		
Resident Subsistence Farmer (adult)	34	2.9E-03
Resident Subsistence Farmer (child)	160	2.8E-03
Subsurface Soil		
Resident Subsistence Farmer (adult)	0.14	1.5E-05
Resident Subsistence Farmer (child)	0.88	1.7E-05
Sediment		
Fire/Dust Suppression Worker	0.0085	2.2E-07
Hunter/Trapper	0.0017	5.5E-08
National Guard Trainee	2.2	2.8E-05
Resident Subsistence Farmer (adult)	0.88	2.2E-05
Resident Subsistence Farmer (child)	6.6	2.5E-05
Surface Water		
Fire/Dust Suppression Worker	0.098	2.9E-06
Hunter/Trapper	0.023	4.0E-07
National Guard Trainee	1.1	1.5E-05
Resident Subsistence Farmer (adult)	2.4	8.1E-05
Resident Subsistence Farmer (child)	6.5	6.6E-05
Waterfowl		
Hunter/Trapper	7.1	2.5E-04

[a] Surface soil is defined as 0 to 1 ft (shallow surface soil) for all receptors except the National Guard Trainee. Surface soil is defined as 0 to 3 ft below ground surface (deep surface soil) for the National Guard Trainee.

[b] Agricultural foodstuffs include milk, beef, and vegetables.

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

Risks and hazards were evaluated and RGOs calculated for the Hunter/Trapper and Fire/Dust Suppression Worker as the representative receptors. Results for these receptors are discussed below for each medium.

- No surface soil COCs were identified for the Hunter/Trapper and Fire/Dust Suppression Worker. Total HIs were 0.00052 and 0.0027 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Total ILCRs were 6.3E-08 and 2.5E-07 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively.

- No sediment COCs were identified for either receptor at EBG. Total HIs were 0.0017 and 0.0085 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Total ILCRs were 5.5E-08 and 2.2E-07 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively.

- One metal (arsenic) was identified as a carcinogenic COC for the Fire/Dust Suppression Worker exposed to surface water at EBG. Total HIs were 0.023 and 0.098 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Total ILCRs were 4.0E-07 and 2.9E-06 for the Hunter/Trapper and Fire/Dust Suppression Worker, respectively. Risk-based RGOs were computed for arsenic at a TR of 10^{-5} and a THI of 1; however, the EPC used in this HHRA for arsenic (0.072 mg/L) was smaller than the most conservative risk-based RGO (0.253 mg/L for the Fire/Dust Suppression Worker, based on a TR of 10^{-5}).

- Waterfowl concentrations were conservatively modeled for all COPCs identified in the sediment and surface water at EBG. The total estimated ILCR and HI for ingestion of hypothetical waterfowl exposed exclusively at EBG are 2.5E-04 and 7.1, respectively. Because of the high level of uncertainty associated with modeling tissue concentrations and the actual location of exposure of wildfowl harvested at EBG, RGOs are not calculated for this indirect exposure pathway.

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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 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 EBG. A BERA follows 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 1989b) and in a subsequent document (EPA 1991b). 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 1992b). 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 1997c, 1998) supersedes *RAGS, Volume II* (EPA 1989b). 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 1997c) was used because it provided the clearest information on preliminary or screening ERAs. The Army also has the RVAAP Facility-wide Ecological Risk Work Plan (USACE 2003a) to guide the work at EBG. Additionally, Ohio EPA has guidance, and that too was used, especially for the hierarchy for ecological screening values (ESVs) and toxicity reference values (TRVs) (Ohio EPA 2003). The 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 EBG includes the equivalent of Ohio EPA's Level I Scoping and Level II Screening ERA. The BERA part is Level III.

These guidance 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 of SERA results (Section 7.6).

For the BERA or Tier III, the following sections present the scope and objectives (Section 7.7); the procedural framework (Section 7.8); and the problem formulation (Section 7.9). The results are presented in Section 7.10. There is an uncertainties section (Section 7.11) and a master summary of both SERA and BERA results (Section 7.12).

7.1 SCOPE AND OBJECTIVES

The scope of the ERA is to characterize, in a preliminary way, the risk to plant and animal populations at EBG, including its aquatic environment, from analytes that are present in the surface soil, subsurface 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). For the BERA, specific ecological receptors are utilized.

The SERA used site-specific analyte concentration data for surface soil, sediment, and surface water from various geographical parts of EBG. 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 EBG 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. Deep groundwater is not a medium of concern for ecological receptors. However, shallow groundwater is expected to flow into the pond on EBG. Groundwater is treated as surface water once it surfaces and mixes with existing surface water. In addition, the section contains an ecological CSM, selection of a receptor, definition of exposure pathways, and selection of assessment endpoints and measures.

The objective of the BERA is to continue the SERA process. The focus is on soil, sediment, and surface water and on specific ecological receptors, e.g., mammals, birds, and aquatic organisms. Its input chemicals are COPECs and the BERA process produces chemicals of ecological concern (COECs).

As an additional element of risk evaluation outside the SERA or BERA, Army guidance (USACE 2003b) directs that ERAs consider extrapolated information from WBG. The Army conducted ground-truthing investigations of plants and animals and how they responded to the chemically contaminated WBG versus the nearby uncontaminated reference (SAIC 2002). The principal item of extrapolation was the plant protection levels for four chemicals. No other WOE comparisons were justified because of the large differences between WBG and EBG site histories, topography, soil type, vegetation, and role of surface water (SAIC 2004).

7.2 PROCEDURAL FRAMEWORK

According to the *Framework for Ecological Risk Assessment* (EPA 1992b), the ERA process consists of three interrelated phases: problem formulation, analysis (composed of exposure assessment and ecological effects assessment), and risk characterization. In conducting the ERA for EBG, 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 ERA 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 receptors, 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 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 EBG. In the SERA 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 FOR THE SCREENING ECOLOGICAL RISK ASSESSMENT

The first step of EPA's approach to the SERA process, problem formulation (data collection and evaluation), includes:

- descriptions of habitats, biota, and 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 EBG. 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 EBG AOC occupies a total area of about 34.6 acres (Table 7-1). This area includes forests and woodlands, shrublands, grasslands, wetlands, old railroad beds, and unpaved roads. The vegetated areas provide habitat for the many plants and animals at Ravenna. Information on plant communities at EBG 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 EBG was conducted in October 2003.

Table 7-1. Plant Communities and Other Habitat Recorded at Erie Burning Ground

Plant Community Type	Acres	% Area
Forest Formations		
Mixed-deciduous Successional Forest	3.1	9.0
Shrubland Formations		
Cephalanthus occidentalis Semi-permanently Flooded Shrubland Alliance	6.0	17.4
Herbaceous Formations		
Nuphar lutea – Nymphaea odorata Permanently Flooded Herbaceous Alliance	3.6	10.4
Typha spp. – (*Scirpus* spp.) Semipermanently Flooded Herbaceous Alliance	19.3	55.9
Other		
Open Water	2.6	7.44
Total	34.6	100.0

Forest Formations

Forest formations 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 formations occur at the EBG AOC.

Mixed-deciduous successional forest

This transitional forest community is fairly abundant at RVAAP and is indicative of a late stage of recovery following significant disturbance (e.g., clear-cutting). A mixture of pioneer species forms the somewhat open canopy. Common species include white ash (*Fraxinus americana*), wild black cherry (*Prunus serotina*), red maple (*Acer rubrum*), black locust (*Robinia pseudoacacia*), quaking aspen (*Populus tremuloides*), and bigtooth aspen (*Populus grandidentata*). At EBG this formation includes pin oak (*Quercus palustris*) and American Beech (*Fagus grandifolia*). Generally, thick shrub and herbaceous layers are presently characterized by old-field species such as gray dogwood (*Cornus racemosa*), northern arrowwood (*Viburnum recognitum*, syn. *dentatum*), blackberry (*Rubus allegheniensis*), hawthorn (*Crataegus* spp.), goldenrod (*Solidago* spp.), sheep sorrel (*Rumex acetosella*), and fescue grasses (*Festuca* spp., mostly *Festuca arundinacea*). This community is located along the northwestern and southeastern corners of EBG. This forest type makes up about 3.1 acres or 9.0% of the EBG 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) less than 20 ft tall. 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 EBG AOC.

Cephalanthus occidentalis **Semipermanently Flooded Shrubland Alliance**

This shrub swamp alliance is dominated by woody species including buttonbush (*Cephalanthus occidentalis*), winterberry (*Ilex verticillata*), swamp rose (*Rosa palustris*), common elder (*Sambucus canadensis*), northern arrowwood (*Viburnum recognitum*), willows (*Salix* spp.), and silky dogwood (*Cornus amomum*). At EBG narrow-leaf or white meadow-sweet (*Spiraea alba*) has colonized a lot of this habitat. Pin oak (*Quercus palustris*) and red maple (*Acer rubrum*) are found in less inundated border areas. Herbaceous species include false nettle (*Boehmeria cylindrica*), mad-dog skullcap (*Scutellaria laterifolia*), water parsnip (*Sium suave*), beggar-ticks (*Bidens* spp.), manna grass (*Glyceria* spp.), sedges (*Carex* spp.), cinnamon fern (*Osmunda cinnamomea*), rice cut-grass (*Leersia oryzoides*), and smartweeds (*Polygonum* spp.). Floating aquatics such as duckweed (*Lemna* spp.) are common in deeper water (> 1 to 2 ft). In addition, *Sphagnum* hummocks occasionally grow around shrub stem-bases. This alliance occupies shallow water areas (e.g., depressions, ponds, floodplains) throughout the eastern United States. In some environments it is a dense shrub-thicket and in others it is open shrubland interspersed with areas of open water. At EBG this community type occurs along the southern half of the AOC, especially around the east and south surface water basins. This shrubland formation makes up about 6.0 acres or 17.4% of the EBG 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 EBG AOC.

Typha **spp.-(*Scirpus* spp.) Semipermanently Flooded Herbaceous Alliance**

The cattail marsh alliance occurs along pond edges, roadside ditches, and shallow basins and is very common throughout the United States. The alliance is dominated by pure stands of narrow-leaf (*Typha angustifolia*) and broad-leaf (*Typha latifolia*) cattails. Sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), and broad-leaf hydrophytic herbs also are common. There is a large infestation of common reed (*Phragmites arundinacea*), an exotic, invasive pest plant that covers about 1 to 2 acres in the northwest corner of the north surface water basin. Saturated or inundated conditions prevail during much of the growing season. Examples of this alliance can be found throughout the center of the AOC. This herbaceous formation makes up about 19.3 acres or 55.9% of the EBG AOC (Table 7-1).

Nuphar lutea - Nymphaea odorata **Permanently Flooded Herbaceous Alliance**

This alliance occurs in permanently flooded areas such as shallow ponds or lakes with depths generally less than 1.5 ft. Hydromorphic rooted plants such as spatterdock (*Nuphar lutea*) and white water lily (*Nymphaea odorata*) dominate the community. At RVAAP ponds, spatterdock is much more common than white water lily. Duckweed species (*Lemna* spp.) and pondweed species (*Potamogeton* spp.) also are common. A large example of this alliance is the marsh area adjacent to boundary fence in the north-central section of the AOC. This herbaceous formation makes up about 3.6 acres or 7.4% of the EBG AOC (Table 7-1).

Other Landscape Features

Other landscape features at EBG include shallow ponds (the east, north, and south surface water basins). The size and depth of these ponds are influenced by beaver dams located off-site to the west. The ponds also fluctuate seasonally and vary according to rainfall patterns. In drier years, the ponds nearly dry up completely by late summer or fall. The area covered by the three surface water basins may cover from about 2.6 acres or 7.4 % of the AOC during dry years with minor beaver activity to as much as 7.3 acres or 21.2% of the area in wet years and maximum beaver activity. Expansion of open water during wet years occurs largely at the expense of the herbaceous communities (Table 7-1).

7.3.1.2 Forestry resources and management

EBG is within Forest Management Compartment 10 of the ten compartments designated within RVAAP. Each compartment is further subdivided into cutting units with the cutting unit boundaries reflecting topographic features (e.g., creeks and roads) rather than forest types. Of Compartment 10's total 1,916 acres, 689 acres are in sawtimber, 483 acres are in poletimber, and 1,544 acres are in timber stands considered to be of adequate regeneration. Areas of inadequate forest regeneration and non-forested areas total 372 acres within Compartment 10. No specific timber stand improvement prescriptions are currently in place for Forest Management Compartment 10. The timber harvest schedule for RVAAP forests shows Forest Management Compartment 10 being harvested during 2011 with an expected allowable harvest of almost 400,000 board ft (Doyle Rule) (OHARNG 2001).

EBG supports only 3 acres (9% of this AOC's total area) of forest. This forested area is a mixed-deciduous successional forest indicative of a late stage of recovery following a significant disturbance such as clear-cutting (SAIC 1999).

7.3.1.3 Special management considerations

Special Interest Areas and Sensitive Areas

As a result of state and federal interagency consultation and the flora and plant inventories conducted at the RTLS/RVAAP, and in accordance with AR 200-3, some "Special Interest Areas" have been established. Special Interest Areas include communities that host state-listed species, are representative of historic ecosystems, and/or are otherwise noteworthy (OHARNG 2001).

Several types of plant communities are considered noteworthy on RVAAP. Noteworthy forested communities include beech-sugar maple forest, oak-maple swamp forest, mixed swamp forest, oak-maple-tuliptree forest, oak-hickory forest, mixed floodplain forest, and successional woods. Noteworthy wetland communities include floating-leaved marsh, submergent marsh, emergent marsh, cattail marsh, sedge-grass meadow, mixed shrub swamp, buttonbush swamp, shrub bog, wet fields, ponds, and disturbed wetlands (OHARNG 2001).

Although the ODNR and the U.S. Fish and Wildlife Service did not identify any sensitive habitats on or near EBG during their natural heritage data searches (OHARNG 2001), this area is included within the eastern border of Special Interest Area Unit 1 (OHARNG 2001).

Special Interest Area Unit 1 was increased from the original area designated by Andreas (1993) to include the EBG beaver ponds (as well as the North Patrol Pond, additional swamp forest, and more of the South Fork of Eagle Creek basin) (OHARNG 2001). These areas were added because of their importance to wildlife, rare plant species, and making Unit 1 a more functional ecosystem. Unit 1 surrounds Unit 2

(Wadsworth Glen). The boundaries include the hayfields (TVMA) on either side of Paris-Windham Road (OHARNG 2001).

The swamp forest along Blackberry Lane (the road that forms the northern border of EBG) is one of the best examples of a swamp forest community in northern Ohio. This community is identified as a Pin Oak-Swamp White Oak-Red Maple Flatwoods Forest by The Nature Conservancy (TNC). The TNC ranks this as a G2 community, indicating that the community is imperiled globally because rarity (6 to 20 occurrences) or because of some factor(s) making it very vulnerable to extinction throughout its range (OHARNG 2001).

The EBG beaver impoundments and associated wetlands contain several plant species that are uncommon at RVAAP. These species include *Carex stricta* (tussock sedge), *Cicuta bulbifera* (bulbiferous water-hemlock), *Ranunculus pensylvanicus* (bristly crowfoot), and *Rumex orbiculatus* (swamp dock). EBG contains no state-listed plant species but it is an important wetland for wildlife, including two state-listed bird species, the sora (*Porzana carolina*) and the Virginia rail (*Rallus limicola*) (OHARNG 2001).

EBG also falls within a 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 extensive 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 highly probable that jurisdictional wetlands would be found within EBG if a jurisdictional delineation were to be performed (Morgan 2004).

A jurisdictional wetland refers to a habitat that has a combination of soil/sediment, surface water, and vegetation that meets several criteria from the government for each element of the combination. For example, soil/sediment needs to be of a certain organic content and type; surface water needs to be present a high percentage of the year; while vegetation must consist of certain grasses, sedges, and other plant species.

Ohio Rapid Assessment

The Ohio rapid assessment method for wetlands (Ohio EPA 2001) was applied at EBG. Habitat sketches, the scoring boundary worksheet, narrative rating, and quantitative rating are found in Appendix O (Part 1). The total score was 81, which indicates a high-quality wetland habitat.

Beyond this brief introduction, the following details are provided about the methods and the results from the Ohio Rapid Assessment for Wetlands. Regarding methods, there are six parts: background information (e.g., location, including a map), scoring boundary worksheet (e.g., boundary definition in the field), narrative rating (e.g., identification of type of wetland such as bog, fen, forest wetland, and so forth), quantitative rating (e.g., field measurements about size, sources of water, floodplain information, and numerical score about these characteristics), summary worksheet (self-explanatory), and wetland categorization worksheet (a page of steps to determine the category from 1 to 3). Regarding results, the wetlands at EBG received a total score of 81. This is a rather high score and as stated means that the wetland is of rather high quality. For example, the hydrology score the maximum points of 30 and other metrics such as soil/sediment and plant communities received high individual scores to make the total of 1.

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 and 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; however, EBG is not included in the deer hunting program (ODNR 1997).

The plant communities within the EBG AOC also provide varied habitats that support several species of animals. The 24 acres of cattail marsh and spatterdock-water lily habitats, along with the 2.5 acres of open water support wetland birds such as red-winged blackbirds (*Agelaius phoeniceus*), great blue herons (*Ardea herodias*), tree swallows (*Tachycineta bicolor*), wood ducks (*Aix sponsa*), and mallards (*Anas platyrhynchos*). Muskrat (*Ondatra zibethicus*) are also likely inhabitants of this habitat (ODNR 1997).

About 9% (3 acres) of EBG is covered by a late-stage successional habitat. This habitat is located along the northwestern and southeastern corners of EBG. Common bird species that use this habitat with its somewhat open canopy include the song sparrow (*Melospiza melodia*), common yellowthroat (*Geothylpis trichas*), gray catbird (*Dumetella carolinensis*), rufous-sided towhee (*Pipilo erythrophthalmus*), and American goldfinch (*Carduelis tristis*). 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*), short-tailed shrew (*Blarina brevicauda*), and meadow vole (*Microtus pennsylvanicus*) are common small mammals (ODNR 1997).

7.3.1.5 Aquatic habitats

Beaver impoundments, drainage channels, ditches, swamp, and marshes can cover up to 90% of the habitat at EBG during periods of normal precipitation. Depending upon climatic trends, such as extended drought over several years, this aquatic habitat can temporarily dwindle to 10 to 20% of this AOC's approximately 35 acres.

Streams and Ditches

A main drainage channel and six drainage ditches were constructed to control surface runoff from EBG (see Figure 1-5). The main drainage channel runs roughly north-south, entering the area beneath Blackberry Lane and bisecting EBG as it drains to the south, where it turns west and exits the area through a 48-in. reinforced concrete pipe. The total length of the main drainage channel through EBG is about 1,700 ft. The remaining ditches bound the T-Area. The much shorter drainage Ditches 1 and 2 are to the east of and parallel the main drainage channel. Ditch 1 is on the west side of the T-Area and Ditch 2 is on the east side. Ditches 3 and 4 are perpendicular and connect directly to the main drainage channel, with Ditch 3 also connecting to the southern end of Ditch 1. Ditch 5, coming from the east, connects at a right angle to the southern end of Ditch 2, while Ditch 6, also running east to west, connects in line to the east end of Ditch 4. Each of the drainage ditches is approximately 250 ft long. This being said, the main channel and ditches currently present themselves as linear stretches of open water habitat within what is currently a combination of beaver impoundments, swamp, and marshes.

Beaver Impoundments

A complex of relatively shallow open water swamp and marshes has been formed within EBG and by beaver activity. About 2.6 acres of open water and roughly 24 acres of associated swamp (3.6 acres) and marsh (19.3 acres) combine with the ditch network to create aquatic habitat.

An inventory of fish species performed at RVAAP included sampling within streams, lakes, ponds, and beaver impoundments. The beaver impoundments at EBG were listed as “beaver flooding at northeast corner of Ravenna Arsenal, Windham Township, Portage County, east side of Trumbull County line” (ODNR 1997). A total of six fish species were collected, including bluegill (*Lepomis macrochirus*) and pumpkinseed sunfish (*Lepomis gibbosus*), grass pickerel (*Esox americanus vermicula*), central mudminnow (*Umbra limi*), golden shiner (*Notemigonus crysoleucas*), and brown bullhead (*Amieurus nebulosus*). Additional species common to RVAAP beaver impoundments not found within EBG during the 1993 survey are largemouth bass (*Micropterus salmoides*) and green (*Lepomis cyanellus*) and warmouth (*Lepomis gulosus*) sunfish (ODNR 1997). Additional fish surveys were also performed within the EBG beaver impoundments during 1999 and 2003 (Morgan 2004). Data from these surveys will be added when they become available.

Beaver impoundments at RVAAP tend to have fish communities different from those found in the streams and artificial ponds (ODNR 1997). The age of the impoundment, water depth, and the extent and diversity of submerged aquatic vegetation influence the development of a fish community. Generally, the older the impoundment, the more diverse the fish community becomes. As a whole, the fish communities in the RVAAP beaver impoundments are similar to those found in the glacial kettlehole lakes of northeastern Ohio and to wetlands and beaver impoundments in south central Ohio (D. Rice, unpublished data, *cited in* ODNR 1997).

USACE/Ohio EPA Surface Water Study

A facility-wide surface water investigation is ongoing by USACE with cooperation of Ohio EPA. In the investigation, water and sediment samples were taken from locations along major stream and tributaries, ponds, and wetlands throughout RVAAP at locations that could have been impacted by former facility activities and sites where the streams entered RVAAP. Fish were caught, identified, and released in the sampling locations corresponding to the water and sediment sample locations. Invertebrate biota was collected by Hester-Dendy samplers set in the same locations and by qualitative sampling of organic debris and rocks in the stream reach. Funnel traps were additionally place in ponds and wetlands for further invertebrate sampling. The pond at EBG was among the sampled water bodies. The details of the study, locations, techniques, and results from this study are published in the Ravenna Facility-wide Surface Water Study: Streams and Ponds (USACE 2005).

By way of summary, surface water quality in EBG, although slightly exceeding several chronic waster quality criteria (WQC), did not appear to impact the biological community. Water quality conditions were comparable to reference ponds. Based on sediment sampling results, moderate contamination was evident in EBG. Particularly noteworthy were elevated levels of several explosive compounds in the sediment.

Macroinvertebrate communities in EBG were substantially different from the reference wetland Snow Pond, which may be the result of the different plant communities and the soft anoxic sediments at EBG, as well as potential sediment contamination. The fish community was not sampled due to shallow water depth.

7.3.1.6 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 EBG are as follows:

Terrestrial EUs:

- Surface soil (0 to 1 ft bgs),
- Subsurface soil (1 to 3 ft bgs).

Sediment EU:

- AOC-wide (hereafter termed ponds).

Surface water EU:

- AOC-wide (hereafter termed ponds).

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) and the Army's RVAAP Facility-wide

Ecological Risk Work Plan (USACE 2003b. 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 O-1 (Part 2) 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 site-related chemicals 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 EBG 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 (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 (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 Ohio Administrative Code (OAC) WQC (Ohio EPA 2002) 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 O-2 through O-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 1999). However, that reference has been superceded by *Region 5 Corrective Action, Ecological Screening Levels (2003)* (EPA 2003).

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 1999b). However, this reference has been superceded by *Region 5 Corrective Action, Ecological Screening Levels (2003)* (EPA 2003b).

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, recommended 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, subsurface soil, sediment, and surface water are presented in Appendix Tables O-5 through O-8, respectively. A summary of these results of the data and media evaluation screening is provided below.

Surface Soil. Fifty-three detected COIs, including 24 inorganics, 9 explosives, 17 SVOCs, and 3 VOCs were inputted to the data and media evaluation for surface soil (Appendix Table O-5). One inorganic (selenium) and four explosives (2,4-DNT; 2,6-DNT; RDX; and 1,3,5-TNB) were eliminated from being COPECs due to a frequency of detection less than 5% and not being PBT compounds. Thus, 48 of the 53 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.

Subsurface Soil. Forty-three detected COIs, including 23 inorganics, 6 explosives, 11 SVOCs, and 3 VOCs were inputted to the data and media evaluation for subsurface soil (Appendix Table O-6). Seven COIs (two inorganics, four explosives, and one SVOC) were eliminated from being COPECs due to a frequency of detection less than 5% and not being a PBT compound. In addition, 12 more COIs were eliminated from being COPECs due their MDC being less than background. Thus, only 24 of the 43 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. Fifty-eight detected COIs, including 23 inorganics, 10 explosives, 2 pesticides/PCBs, 18 SVOCs, and 5 VOCs were inputted to the data and media evaluation for EBG sediment (Appendix Table O-7). Ten COIs were eliminated from being COPECs because their frequency of detection was less than 5% and they were not PBT compounds. In addition, two inorganics (potassium and thallium) were eliminated from being COPECs because their MDCs did not exceed the Ohio EPA SRVs and they were not PBTs. Thus, 46 of the 58 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. Thirty-nine detected COIs, including 22 inorganics, 7 explosives, 2 SVOCs, and 8 VOCs were inputted to the data and media evaluation for EBG surface water (Appendix Table O-8). Seven of the COIs (beryllium, selenium, three explosives, and three VOCs) were eliminated from being COPECs because their frequency of detection was less than 5% and they were not PBT compounds. Thus, 32 of the 39 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 O-2 through O-4. Tables showing the results of the media screening for surface soil, subsurface soil, sediment, and surface water are presented in Appendix Tables O-9 through O-12, respectively. Summary results of the retained COPECs following the media screening are presented in Tables 7-2 through 7-5 and are discussed below.

7.4.2.1 Surface soil media screening

The media screening for surface soil is shown in Appendix Table O-9. A summary of surface soil COPECs that were retained following the media screening is presented in Table 7-2.

Forty-eight COPECs were inputted into the media screening from the data and media evaluation, including 23 inorganics, 5 explosives, 17 SVOCs, and 3 VOCs (Appendix Table O-9). Eight of the inputted COPECs were not retained because their maximum detects were below their ESVs and they were not PBT compounds. The eight eliminated COPECs included three inorganics (beryllium, cobalt, and thallium), one explosive (2,4,6-TNT), and three VOCs (acetone, methylene chloride, and toluene). Thus, 40 COPECs were retained, which included 20 inorganics, 4 explosives, and 16 SVOCs.

Of the 40 retained COPECs, 18 had maximum detects that exceeded their ESV (16 inorganics and 2 SVOCs), 10 had no ESVs, (4 inorganics, 4 explosives, and 2 SVOCs), and 13 were COPECs solely due to being PBT compounds (all were SVOCs) (Table 7-3). Six of the retained COPECs (cadmium, lead, mercury, zinc, and 2 SVOCs) had maximum detects that exceeded the ESV and were also PBT compounds.

7.4.2.2 Sediment media screening

The media screening for EBG sediment is shown in Appendix Table O-11. A summary of sediment COPECs that were retained following the media screening is presented in Table 7-5.

Forty-six sediment COPECs were inputted into the media screening from the data and media evaluation, including 21 inorganics, 4 explosives, 2 pesticides/PCBs, 16 SVOCs, and 3 VOCs (Appendix Table O-11). Two of the inputted COPECs were not retained because their maximum detects were below their ESVs and they were not PBT compounds. The two eliminated COPECs included one inorganic (cobalt) and one VOC (toluene). Thus, 44 COPECs were retained, which included 20 inorganics, 4 explosives, 2 pesticides/PCBs, 16 SVOCs, and 2 VOCs.

Table 7-2. Summary of Surface Soil COPECs for Erie Burning Ground 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		
Barium	X		
Cadmium	X	X	
Calcium			X
Chromium	X		
Copper	X		
Cyanide	X		
Iron	X		
Lead	X	X	
Magnesium			X
Manganese	X		
Mercury	X	X	
Nickel	X		
Potassium			X
Silver	X		
Sodium			X
Vanadium	X		
Zinc	X	X	
Organics-Explosives			
2-Amino-4,6-dinitrotoluene			X
4-Amino-2,6-dinitrotoluene			X
Nitrocellulose			X
4-Nitrotoluene			X
Organics-Semivolatiles			
Acenaphthylene		X	X
Anthracene		X	
Benzo(*a*)anthracene		X	
Benzo(*a*)pyrene	X	X	
Benzo(*b*)fluoranthene		X	
Benzo(*g*,*h*,*i*)perylene		X	
Benzo(*k*)fluoranthene		X	
Bis(2-ethylhexyl)phthalate	X	X	
Carbazole		X	X
Chrysene		X	
Dibenzo(*a*,*h*)anthracene		X	
Fluoranthene		X	
Indeno(1,2,3-*cd*)pyrene		X	
Naphthalene		X	
Phenanthrene		X	
Pyrene		X	

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
PBT = Persistent, bioaccumulative, and toxic.
“X” = COPEC was retained based on this rationale.

Table 7-3. Summary of Subsurface Soil COPECs for Erie Burning Ground and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum detect > ESV	PBT compound	No ESV
Inorganics			
Antimony	X		
Cadmium	X	X	
Copper	X		
Lead	X	X	
Mercury	X	X	
Sodium			X
Zinc	X	X	
Organics-Explosives			
Nitrocellulose			X
Organics-Semivolatiles			
Benzo(*a*)anthracene	X	X	
Benzo(*a*)pyrene	X	X	
Benzo(*b*)fluoranthene	X	X	
Benzo(*k*)fluoranthene	X	X	
Bis(2-ethylhexyl)phthalate		X	
Chrysene	X	X	
Fluoranthene	X	X	
Indeno(1,2,3-*cd*)pyrene	X	X	
Phenanthrene	X	X	
Pyrene	X	X	

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
PBT = Persistent, bioaccumulative, and toxic.
"X" = COPEC was retained based on this rationale.

Table 7-4. Summary of Sediment COPECs for Erie Burning Ground 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		
Barium			X
Beryllium			X
Cadmium	X	X	
Calcium			X
Chromium	X		
Copper	X		
Cyanide	X		
Iron			X
Lead	X	X	
Magnesium			X
Manganese			X
Mercury	X	X	
Nickel	X		
Silver	X		
Sodium			X
Vanadium			X
Zinc	X	X	
Organics-Explosives			
2,6-Dinitrotoluene	X		
Nitrobenzene	X		
Nitrocellulose			X
2,4,6-Trinitrotoluene			X
Organics-Pesticides/PCBs			
PCB-1254	X	X	
Methoxychlor		X	
Organics-Semivolatiles			
Benzo(*a*)anthracene	X	X	
Benzo(*a*)pyrene	X	X	
Benzo(*b*)fluoranthene		X	
Benzo(*g*,*h*,*i*)perylene		X	
Benzo(*k*)fluoranthene	X	X	
Bis(2-ethylhexyl)phthalate	X	X	
Butylbenzyl phthatlate		X	
Carbazole		X	X
Chrysene	X	X	
Di-n-butylphthalate	X	X	
Fluoranthene	X	X	
Fluorene	X	X	
Indeno(1,2,3-*cd*)pyrene	X	X	
N-Nitrosodiphenylamine		X	X
Phenanthrene	X	X	
Pyrene	X	X	
Organics-Volatiles			
Acetone	X		
2-Butanone	X		

COPEC = Chemical of potential ecological concern.
ESV = Ecological screening value.
PBT = Persistent, bioaccumulative, and toxic compound.
PCB = Polychlorinated biphenyl.
“X” = COPEC was retained based on this rationale.

Table 7-5. Summary of Surface Water COPECs for Erie Burning Ground and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > OAC WQC	**PBT compound**	**No OAC WQC**
Inorganics			
Aluminum			X
Barium	X		
Cadmium		X	
Calcium			X
Copper	X		
Cyanide	X		X
Iron			
Lead	X	X	
Magnesium			X
Manganese			X
Mercury		X	
Potassium			X
Sodium			X
Zinc	X	X	
Organics-Explosives			
Nitrocellulose			X
Organics-Volatiles			
Acetone			X
Chloromethane			X

COPEC = Chemical 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 Subsurface soil media screening

The media screening for subsurface soil is shown in Appendix Table O-10. A summary of subsurface soil COPECs that were retained following the media screening is presented in Table 7-4.

Twenty-four COPECs were inputted into the media screening from the data and media evaluation, including nine inorganics, two explosives, ten SVOCs, and three VOCs (Appendix Table O-10). Six of the inputted COPECs (including all three VOCs) were not retained because their maximum detects were below their ESVs and they were not PBT compounds. The six eliminated COPECs included two inorganics (barium and beryllium), one explosive (2,4,6-TNT), and three VOCs (acetone, methylene chloride, and toluene). Thus, 18 COPECs were retained, which included 7 inorganics, 1 explosive, and 10 SVOCs.

Of the 18 retained COPECs, 15 had maximum detects that exceeded their ESV (6 inorganics and 9 SVOCs), 2 had no ESVs (sodium and nitrocellulose), and 1 SVOC was a COPEC solely due to being a PBT compound (Table 7-4). Twelve of the retained COPECs (cadmium, lead, mercury, zinc, and eight SVOCs) had maximum detects that exceeded the ESV and were also PBT compounds.

Of the 44 retained COPECs, 26 had maximum detects that exceeded their ESV (10 inorganics, 2 explosives, 1 PCB, 11 SVOCs, and 2 VOCs), 14 had no ESVs (10 inorganics, 2 explosives, and 2 SVOCs), and 6 were COPECs solely due to being PBT compounds (methoxychlor and 5 SVOCs)

(Table 7-5). Sixteen of the retained COPECs (cadmium, lead, mercy, zinc, methoxychlor, and 11 SVOCs) had maximum detects that exceeded the ESV and were also PBT compounds.

7.4.2.4 Surface water media screening

The media screening for EBG surface water is shown in Appendix Table O-12. A summary of surface water COPECs that were retained following the media screening is presented in Table 7-6.

Table 7-6. Summary of Surface Water COPECs for Erie Burning Ground and Their Rationale for Retention

Retained COPEC	Rationales for COPEC Retention		
	Maximum Detect > OAC WQC	**PBT compound**	**No OAC WQC**
Inorganics			
Aluminum			X
Barium	X		
Cadmium		X	
Calcium			X
Copper	X		
Cyanide	X		X
Iron			
Lead	X	X	
Magnesium			X
Manganese			X
Mercury		X	
Potassium			X
Sodium			X
Zinc	X	X	
Organics-Explosives			
Nitrocellulose			X
Organics-Volatiles			
Acetone			X
Chloromethane			X

COPEC = Chemical 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.

Thirty-two surface water COPECs were inputted into the media screening from the data and media evaluation, including 20 inorganics, 5 explosives, 2 SVOCs, and 5 VOCs (Appendix Table O-12). Fifteen of the inputted COPECs (six inorganics, four explosives, both SVOCs, and three VOCs) were not retained because their maximum detects were below their OAC WQC. Thus, 17 COPECs were retained, which included 14 inorganics, 1 explosive, and 2 VOCs.

Of the 17 retained COPECs, 5 had maximum detects that exceeded the OAC WQC, 10 had no OAC WQC (7 inorganics, 1 explosive, and both VOCs), and 2 were COPECs solely due to being PBT compounds (cadmium and mercury) (Table 7-6). Two of the retained COPECs (lead and zinc) had maximum detects that exceeded the ESV and were also PBT compounds.

7.4.2.5 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 EBG 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 Scientific Management Decision Point (SMDP) was chosen to continue the ecological assessment in a Level III ERA” (Ohio EPA 2003). The SMDP was made before the Level II evaluation that if the conditions for potential for hazard were demonstrated at the EBG 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 EBG 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 1 ft bgs. Subsurface soil is defined as 1 to 3 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.

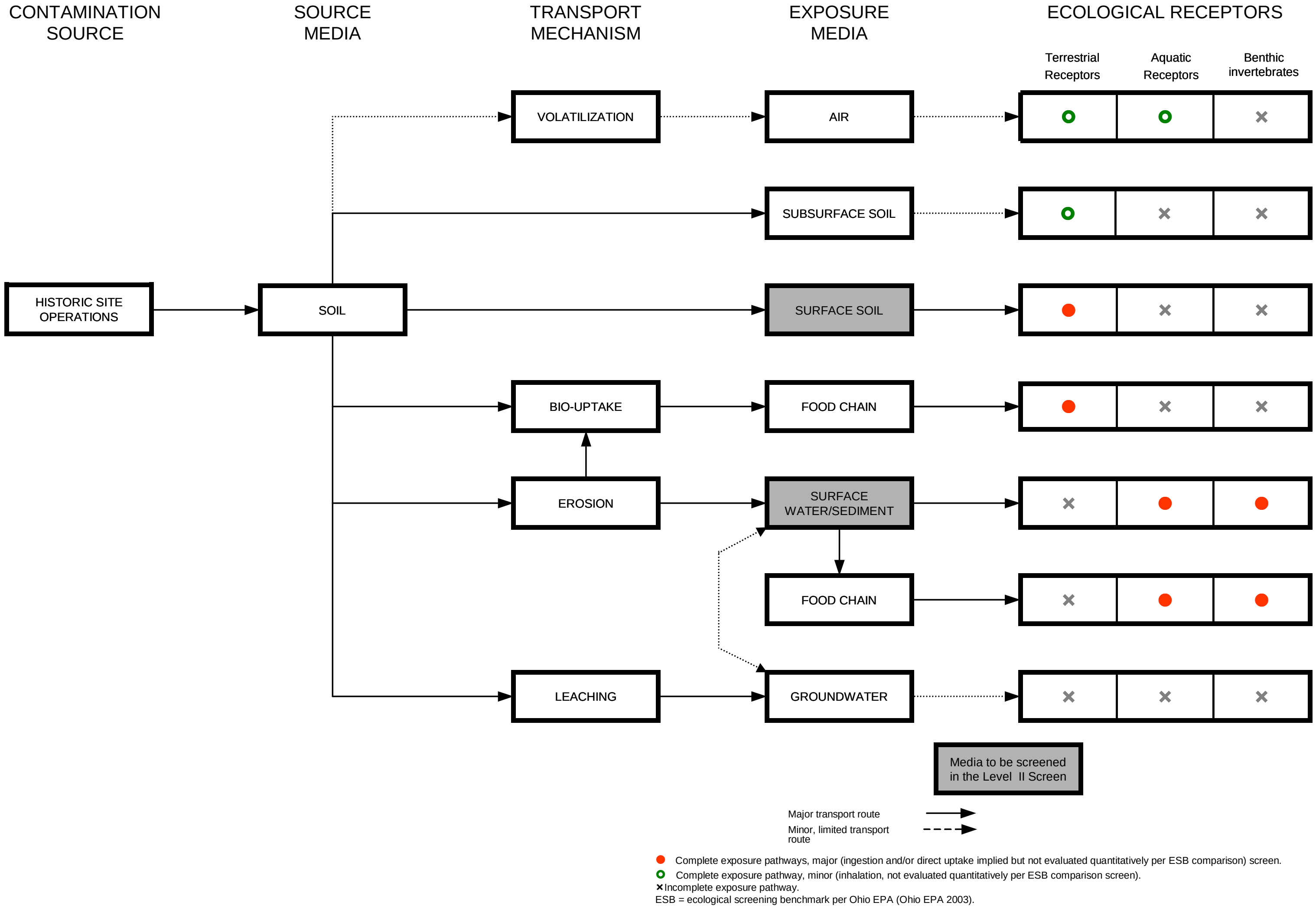
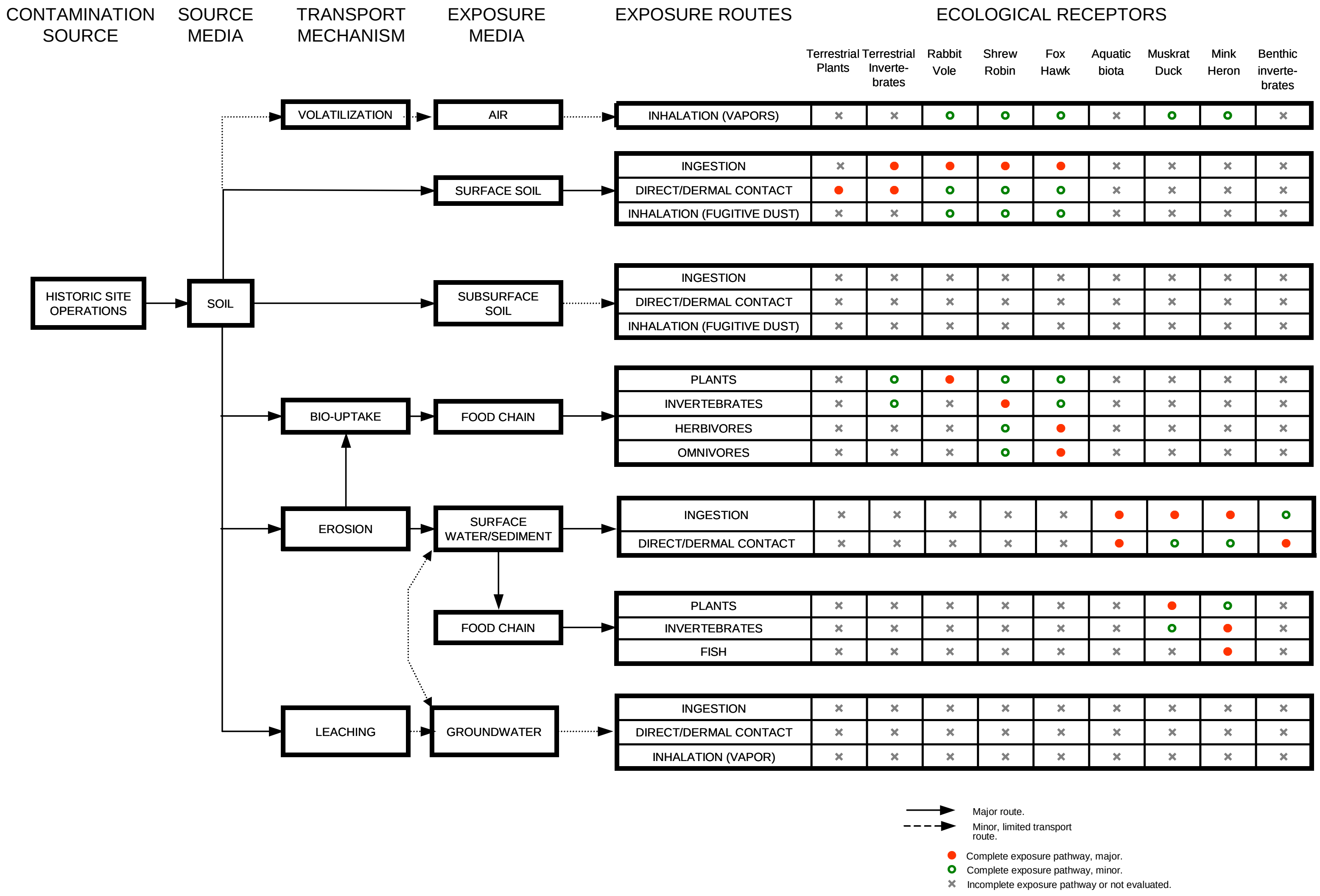


Figure 7-1. Conceptual Site Model for Level II Screen – Pathways for Ecological Exposure at the Erie Burning Ground Site



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)	×	×	×	×	×	×	×	×	×

→ Major route.
--→ Minor, limited transport route.
● Complete exposure pathway, major.
○ Complete exposure pathway, minor.
× Incomplete exposure pathway or not evaluated.

Figure 7-2. Conceptual Site Model for Level III Screen – Pathways for Ecological Exposure at the Erie Burning Ground Site

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 and subsurface soil, food chain, surface water, and sediment. 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 medium until it does so. Soil, surface water, sediment, and food chain are the principal exposure media for the EBG 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) would 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 and subsurface soil include ingestion (for terrestrial invertebrates, rabbits, shrews, foxes, and hawks) and direct contact (for terrestrial plants and invertebrates). The ingestion exposure route for rabbits, shrews, robins, foxes, and hawks includes soil, as well as plant and/or animal food (i.e., food chain), that were exposed to the surface soil. Minor exposure routes for surface soil include direct contact and inhalation of fugitive dust (for rabbits, shrews, 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 likely 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, shrews, 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 (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 EBG, the following types of ecological receptors are likely to be present: terrestrial plants, terrestrial invertebrates, cottontail rabbits (*Sylvilagus floridanus*), short-tailed shrews (*Blarina brevicauda*), 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 Section 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 EBG 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 EBG site.

Terrestrial Invertebrate Exposure to Soil

Terrestrial invertebrate exposure to soil is applicable to soils for the EBG 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 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 EBG site.

Mammalian Herbivore Exposure to Soil

Mammalian herbivore exposure to soil is applicable to the EBG site. Cottontail rabbits represent mammalian herbivore receptors, and there is suitable habitat present for them at the site. This species has 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 are components of the diet of terrestrial top predators.

Cottontail rabbits 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. Thus, there is sufficient justification to warrant cottontail rabbits as receptors for the EBG site.

Insectivorous Mammal and Bird Exposure to Soil

Insectivorous mammal and bird exposure to soil is applicable to the EBG 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 EBG site.

Terrestrial Top Predators

Exposure of terrestrial top predators is applicable to the EBG 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 EBG site.

7.4.4.2 Aquatic and riparian exposure receptors

The aquatic exposures, receptors, and justification for why they are relevant for the EBG site are presented below.

Exposure of Aquatic Biota to Water

Exposure of aquatic biota to water is applicable to the EBG 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 EBG 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 EBG 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 EBG site.

Riparian Carnivores

Exposure of predators to aquatic biota is applicable to the EBG 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 EBG site.

7.4.5 Relevant and Complete Exposure Pathways

Relevant and complete exposure pathways for the ecological receptors at EBG 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 EBG 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 EBG. 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 1992b). 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 7-7 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 Corps guidance are provided: no further action, risk management, monitoring, remediation, or further investigation. These are the logical options, and the options fitted to the EBG 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, 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), 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, 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 (2003) published guidelines for selection of screening values for soil and sediment, and OAC WQC for surface water.

COPECs that remained after the Level II Screen are 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 RME 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) and the Army’s guidance (USACE 2003b). 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

Table 7-7. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for EBG 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 7-7. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the EBG 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 7-7. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the EBG 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 7-7. Management Goals, Ecological Assessment Endpoints, Measures of Effect, and Decision Rules Identified for the EBG 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.
EBG = Erie Burning Ground.
RME = Reasonable maximum exposure.
SMDP = Scientific management decision point.
TEC =Threshold effect concentration.
TRV = Toxicity reference value.

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, subsurface 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 outcome is to continue the ecological assessment in a Level III BERA. The Level III BERA is presented beginning in Section 7.7.

7.6 SUMMARY OF THE LEVEL II SCREEN

The EBG site contains sufficient terrestrial and aquatic (soil, sediment, and surface water) habitat to support various classes of ecological receptors. For example, terrestrial habitats at EBG include woodlots, marshy areas, and open water. 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 EBG soils, sediment, and surface water using Ohio EPA and Army 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 WQC for surface water. Chemicals whose concentrations exceeded or lacked the ESVs or OAC WQC, as well as chemicals that were PBT compounds, were retained as COPECs while all other chemicals were eliminated from further action.

For surface soil, 53 detected COIs were inputted into the data and media evaluations, wherein 5 were eliminated due to low frequency of detection and not being PBT compounds, so 48 were identified as COPECs and carried forward to the media screening. Of the 48 COPECs inputted into the media screening, 8 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 40 chemicals were retained as COPECs for surface soil.

For subsurface soil, 43 detected COIs were inputted into the data and media evaluations, wherein 19 were eliminated due to either low frequency of detection or MDC being less than background and not being PBT compounds, so 24 were identified as COPECs and carried forward to the media screening. Of the 24 COPECs inputted into the media screening, 6 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 18 chemicals were retained as COPECs for subsurface soil.

For sediment, 58 detected COIs were inputted into the data and media evaluations, wherein 12 were eliminated due to either low frequency of detection or MDCs being less than the Ohio EPA SRVs or background and they were not PBT compounds. Thus, 46 of the 58 detected COIs were identified as COPECs and carried forward to the media screening. Of the 46 COPECs inputted into the media screening, only 2 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 44 chemicals were retained as COPECs for sediment.

For surface water, 39 detected COIs were inputted into the data and media evaluations, wherein 7 were eliminated due to MDCs being less than background and not being a PBT compound. Thus, 32 of the 39 detected COIs were identified as COPECs and carried forward to the media screening. Of the 32 COPECs inputted into the media screening, 15 were eliminated because their concentrations did not exceed their OAC WQC and they were not PBT compounds, so 17 chemicals were retained as COPECs for surface water.

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 EBG site, a recommendation is made to move to a SMDP whose outcome is further evaluation by conducting a Level III BERA. The Level III BERA is presented beginning in Section 7.7

7.7 SCOPE AND OBJECTIVES FOR THE BASELINE ECOLOGICAL RISK ASSESSMENT

The scope of the BERA or Ohio Level III ERA is to characterize the risk to plant and animal populations at EBG, including its aquatic environment, from analytes that are present in the surface soil, subsurface soil, sediment, and surface water. The Army's Ravenna site-wide ecological risk document also guides this work. The principal tool is the HQ for a variety of specific ecological receptors. Details about the general, as well as the SERA, scope and objectives are found in Section 7.1.

7.8 PROCEDURAL FRAMEWORK FOR THE BASELINE ECOLOGICAL RISK ASSESSMENT

According to the *Framework for Ecological Risk Assessment* (EPA 1992b), the BERA process (like the SERA) consists of three interrelated phases: problem formulation, analysis (composed of exposure assessment and ecological effects assessment), and risk characterization. See Section 7.2 for details about these phases.

The BERA is organized by the four interrelated steps of the EPA framework. Sections 7.9 and 7.10 detail the technical issues and data evaluation procedures associated with each step followed by the HQ results. Section 7.11 evaluates the degree of reliability or uncertainty of these methodological steps and the data used. Finally, Section 7.12 provides the summary of BERA methods and results.

7.9 PROBLEM FORMULATION FOR THE BASELINE ECOLOGICAL RISK ASSESSMENT

The first step of EPA's approach to the BERA process, problem formulation (data collection and evaluation), includes the same parts as the SERA detailed in Section 7.3.

7.9.1 Ecological Conceptual Site Model

The ecological CSM of EBG has been developed for the BERA using available site-specific information and professional judgment. The constituent source, exposure media, receptors, and the routes by which they are exposed to constituents are recognized. Figure 7-1 shows the ecological CSM whose parts are explained in Section 7.3.1. Figure 7-2 shows the ecological CSM for specific receptors. The big difference between the SERA and BERA CSMs is the greater specificity of ecological receptors for the BERA.

7.9.2 Selection of Exposure Units

From the ecological assessment viewpoint, an EU is the investigation area and some of the surrounding area where ecological receptors are likely to gather food, seek shelter, reproduce, and move around. The BERA depends on the one soil (two depths) EU and the one sediment EU and one surface water EU as did the SERA (see Section 7.3.2).

7.9.3 Description of Habitats and Populations

The habitats and populations are defined in the SERA (see Section 7.3.1).

7.9.4 Review of Chemicals of Potential Ecological Concern from the Screening Ecological Risk Assessment

7.9.4.1 Summary of the methodology to identify COPECs for the Level II Screening

A Level II scope was applied to concentration data (see Section 7.4) from surface and subsurface soils, sediment, and surface water.

7.9.4.2 Summary of surface soil COPECs from the Level II Screen

The Level II Screen identified the following EU-specific list of surface soil COPECs from the results of the ESV media and PBT screen.

- Aluminum (maximum detect > ESV)
- Antimony (maximum detect > ESV)
- Arsenic (maximum detect > ESV)
- Barium (maximum detect > ESV)
- Cadmium (maximum detect > ESV; PBT compound)
- Calcium (no ESV)
- Chromium (maximum detect > ESV)
- Copper (maximum detect > ESV)
- Cyanide (maximum detect > ESV)
- Iron (maximum detect > ESV)
- Lead (maximum detect > ESV; PBT compound)
- Magnesium (no ESV)
- Manganese (maximum detect > ESV)
- Mercury (maximum detect > ESV; PBT compound)
- Nickel (maximum detect > ESV)
- Potassium (no ESV)
- Silver (maximum detect > ESV)

- Sodium (no ESV)
- Vanadium (maximum detect > ESV)
- Zinc (maximum detect > ESV; PBT compound)
- 2-Amino-4,6-DNT (no ESV)
- 4-Amino-2,6-DNT (no ESV)
- Nitrocellulose (no ESV)
- 4-Nitrotoluene (no ESV)
- Acenaphthylene (PBT compound)
- Anthracene (PBT compound)
- Benzo(*a*)anthracene (PBT compound)
- Benzo(*a*)pyrene (maximum detect > ESV; PBT compound)
- Benzo(*b*)fluroranthene (PBT compound)
- Benzo(*g*,*h*,*i*)perylene (PBT compound)
- Benzo(*k*)fluroranthene (PBT compound)
- Bis(2-ethylhexyl)phthalate (maximum detect > ESV; PBT compound)
- Carbazole (PBT compound)
- Chrysene (PBT compound)
- Dibenzo(*a*,*h*)anthracene (PBT compound)
- Fluoranthene (PBT compound)
- Indeno(1,2,3-*cd*)pyrene (PBT compound)
- Naphthalene (PBT compound)
- Phenanthrene (PBT compound)
- Pyrene (PBT compound).

This list of surface soil COPECs was carried forward to, and was inputted into, the Level III BERA.

7.9.4.3 Summary of subsurface soil COPECs from the Level II Screen

The Level II Screen identified the following EU-specific list of subsurface soil COPECs from the results of the ESV media and PBT screen.

- Antimony (maximum detect > ESV)
- Cadmium (maximum detect > ESV; PBT compound)
- Copper (maximum detect > ESV)
- Lead (maximum detect > ESV; PBT compound)
- Mercury (maximum detect > ESV; PBT compound)
- Sodium (no ESV)
- Zinc (maximum detect > ESV; PBT compound)
- Nitrocellulose (no ESV)
- Benzo(*a*)anthracene (maximum detect > ESV; PBT compound)
- Benzo(*a*)pyrene (maximum detect > ESV; PBT compound)
- Benzo(*b*)fluroranthene (maximum detect > ESV; PBT compound)
- Benzo(*k*)fluroranthene (maximum detect > ESV; PBT compound)
- Bis(2-ethylhexyl)phthalate (PBT compound)
- Chrysene (maximum detect > ESV; PBT compound)
- Fluoranthene (maximum detect > ESV; PBT compound)
- Indeno(1,2,3-*cd*)pyrene (maximum detect > ESV; PBT compound)
- Phenanthrene (maximum detect > ESV; PBT compound)

- Pyrene (maximum detect > ESV; PBT compound).

This list of subsurface soil COPECs was carried forward to, and was inputted into, the Level III BERA.

7.9.4.4 Summary of sediment COPECs from the Level II Screen

The Level II Screen identified the following EU-specific list of sediment COPECs from the one sediment EU, based on the results of the media screen.

- Aluminum (no ESV)
- Antimony (no ESV)
- Arsenic (maximum detect > ESV)
- Barium (no ESV)
- Beryllium (no ESV)
- Cadmium (maximum detect > ESV; PBT compound)
- Calcium (no ESV)
- Chromium (maximum detect > ESV)
- Copper (maximum detect > ESV)
- Cyanide (maximum detect > ESV)
- Iron (no ESV)
- Lead (maximum detect > ESV; PBT compound)
- Magnesium (no ESV)
- Manganese (no ESV)
- Mercury (maximum detect > ESV; PBT compound)
- Nickel (maximum detect > ESV)
- Silver (maximum detect > ESV)
- Sodium (no ESV)
- Vanadium (no ESV)
- Zinc (maximum detect > ESV; PBT compound)
- 2,6-DNT (maximum detect > ESV)
- Nitrobenzene (maximum detect > ESV)
- Nitrocellulose (no ESV)
- 2,4,6-TNT (no ESV)
- PCB-1254 (maximum detect > ESV; PBT compound)
- Methoxychlor (PBT compound)
- Benzo(*a*)anthracene (maximum detect > ESV; PBT compound)
- Benzo(*a*)pyrene (maximum detect > ESV; PBT compound)
- Benzo(*b*)fluroranthene (PBT compound)
- Benzo(*g,h,i*)perylene (PBT compound)
- Benzo(*k*)fluroranthene (maximum detect > ESV; PBT compound)
- Bis(2-ethylhexyl)phthalate (maximum detect > ESV; PBT compound)
- Butylbenzylphthalate (PBT compound)
- Carbazole (PBT compound; no ESV)
- Chrysene (maximum detect > ESV; PBT compound)
- Di-n-butylphthalate (maximum detect > ESV; PBT compound)
- Fluoranthene (maximum detect > ESV; PBT compound)
- Fluorene (maximum detect > ESV; PBT compound)
- Indeno(1,2,3-*cd*)pyrene (maximum detect > ESV; PBT compound)

- N-nitrosodiphenylamine (PBT compound; no ESV)
- Phenanthrene (PBT compound)
- Pyrene (PBT compound)
- Acetone (maximum detect > ESV)
- 2-Butanone (maximum detect > ESV).

This list of sediment COPECs was carried forward to, and was inputted into, the Level III BERA.

7.9.4.5 Summary of surface water COPECs from the Level II Screen

The Level II Screen identified the following EU-specific list of surface water COPECs from the one EU, based on the results of the media screen.

- Aluminum (no OAC WQC)
- Barium (average detect > OAC WQC)
- Cadmium (PBT Compound)
- Calcium (no OAC WQC)
- Copper (average detect > OAC WQC)
- Cyanide (average detect > OAC WQC)
- Iron (no OAC WQC)
- Lead (average detect > OAC WQC; PBT compound)
- Magnesium (no OAC WQC)
- Manganese (no OAC WQC)
- Mercury (PBT Compound)
- Potassium (no OAC WQC)
- Sodium (no OAC WQC)
- Zinc (average detect > OAC WQC; PBT compound)
- Acetone (no OAC WQC)
- Chloromethane (no OAC WQC).

This list of surface water COPECs was carried forward to, and was inputted into, the Level III BERA.

7.9.5 Level III Ecological Exposure Assessment

For Level III, mathematical models are used to calculate the exposure of specific ecological receptors to COPECs, and the exposures are compared to chemical TRVs. COPECs are constituents that remain after the screening step (Sections 7.1 through 7.6). Published chemical- and receptor-specific TRVs were used for COPECs. Each of these toxicity benchmarks is defined later in the text. The BERA scope (Sections 7.7 through 7.12) culminate in a SMDP, which will result in (1) an NFA, (2) whether to conduct a removal or other remedial action, or (3) a more detailed ERA, e.g., Level IV, including field surveys and sampling.

The methods for performing ecological exposure assessment are presented in the following subsections, which describe:

- the Level III and Army approach to using screening and analysis methods (Section 7.9.5.1);
- receptor-specific parameters to be used in the exposure equations (Section 7.9.5.2);
- methods and equations to estimate exposure to COPECs (Section 7.9.5.3); and
- receptor- and chemical-specific exposure parameters (Sections 7.9.5.4 through 7.9.5.7).

7.9.5.1 Site-specific methods approach

The Level III evaluation used an estimate of the RME concentrations in environmental media at each EU to identify COPECs and ecological receptors that require no further analysis. The RME concentration was defined as the lower of the UCL_{95} of the mean and the MDC. RME concentrations and the methods used to calculate the RME concentration for each COPEC at each EU are described in Chapter 4.0.

For direct exposure (terrestrial plants, terrestrial invertebrates, aquatic biota, and benthic invertebrates), the HQ was calculated by dividing the RME concentration in soil, surface water, or sediment by the TRV. For ingestion exposures (mammals and birds), the average daily dose (ADD) was calculated using the exposure equations presented in Section 7.9.5.2. The HQ was calculated by dividing the ADD by the TRV (Section 7.9.6).

Internal concentrations of COPECs were calculated for terrestrial plants, terrestrial invertebrates, aquatic biota, and benthic invertebrates by multiplying the RME concentration of the COPEC by a chemical- and species-specific BCF or BAF (BCFs and BAFs are defined and described in Section 7.9.5.4). Internal concentrations in plants, terrestrial invertebrates, benthic invertebrates, aquatic plants, and aquatic biota were used to calculate ADDs to terrestrial herbivores, terrestrial invertivores, riparian herbivores, and riparian carnivores. Internal concentrations of COPECs in animal prey (small mammals and fish) were used to calculate ADDs to carnivores (Section 7.9.5.3).

Internal concentrations of COPECs in small mammals were calculated by multiplying the ADD by a chemical- and species-specific BAF (Section 7.9.5.4). Internal concentrations of COPECs in fish were used along with sediment or surface water concentrations to calculate the ADD of riparian carnivores (Section 7.9.5.3).

7.9.5.2 Receptor parameters

Calculation of receptor-specific ADDs requires parameters that describe the home range, body weight, food and water intake rates, and diet distribution. The representative receptors for the Level III BERA are described in Section 7.9.5.3. Receptor parameters are not needed for plants, earthworms, benthic invertebrates, or aquatic biota because doses for these receptors are empirically based on contaminant concentrations in soil, sediment, or surface water, rather than calculated. Receptor parameters for the other indicator receptors are shown in Tables O-13 through O-20.

7.9.5.3 Ecological receptors and exposure evaluation for COPECs

The dose that results from the exposure of a receptor to chemicals in soil, sediment, or surface water, both directly and through food chains, is the product of the concentration of the chemical in the ingested medium and exposure factors. Exposure factors describe how much of the available chemical is taken up by the receptor per unit of concentration in the medium. Exposures were calculated for the EU-specific Level III analysis assuming that the most likely contaminated food item makes up 100% of the diet and all of the ingested food is absorbed. It is further assumed that the receptor is present in the vicinity of the site 100% of the time, but it does not necessarily feed on the site all of the time. Therefore, an AUF is calculated for each receptor at each EU (see Section 7.9.5.4).

Equations used to calculate exposure to COPECs were adapted from equations presented in Ohio EPA guidance (Ohio EPA 2003); terms used in this section may differ from those used in the guidance, but the mathematical meaning of each equation matches the corresponding equation in the Ohio EPA guidance (Ohio EPA 2003). Equations are given here for:

- terrestrial plants,
- terrestrial invertebrates,
- terrestrial mammals and birds (rabbit, shrew, fox, and hawk),
- aquatic biota (aquatic invertebrates and fish),
- benthic invertebrates (aquatic insect larvae, crayfish, snails, clams, and bivalves),
- riparian herbivores (muskrat and mallard), and
- riparian carnivores (mink and heron).

Terrestrial plants and invertebrates are exposed by direct contact with soil. Terrestrial animals and birds are exposed to COPECs by ingestion of food and soil. Three kinds of equations were required to calculate the exposures of all terrestrial receptors: an equation for exposure by ingestion of plants and soil; an equation for exposure by ingestion of terrestrial invertebrates and soil; and an equation for exposure of carnivores by ingestion of animal prey and soil.

Terrestrial Plants

Exposure equations are not needed for exposure of terrestrial plants to COPECs because the TRV for plants is the concentration in soil. Therefore, the measure of exposure for plants to a COPEC is the RME concentration of the COPEC in soil at each EU (mg/kg dry weight).

Terrestrial Soil Invertebrates

Exposure equations are not needed for terrestrial invertebrates because the TRV for terrestrial invertebrates is the concentration in soil. Therefore, the measure of exposure for terrestrial invertebrates is the RME concentration of the COPEC in soil at each EU (mg/kg dry weight).

Terrestrial Herbivores (cottontail rabbit)

It was assumed that terrestrial herbivores are exposed by ingestion of plants and soil. The equation for exposure of terrestrial herbivores to a single COPEC in contaminated soil by ingestion of plants and soil (Ohio EPA 2003) is:

$$ADD_{total} = ADD_P + ADD_S \qquad \textbf{(7-1)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_P = Average daily dose (mg/kgBW/day) from ingestion of plants,
ADD_S = Average daily dose (mg/kgBW/day) from ingestion of soil.

The equation for exposure by ingestion of plants (Ohio EPA 2003) is:

$$ADD_P = RME \times SP_v \times CF \times I_P \times AUF \qquad \textbf{(7-2)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

SP_v = Soil-to-plant BCF [mg/kg dry weight per mg/kg dry soil (= kg dry soil/kg dry weight)]. SP_v indicates a diet of vegetative plants,

CF = Correction factor, dry weight to wet weight; assuming 85% water content of plants (Ohio EPA 2003), CF = (1 – 0.85) = 0.15,

I_P = Plant ingestion rate (kg fresh plant/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of soil (Ohio EPA 2003) is:

$$ADD_S = RME \times I_S \times AUF \qquad \textbf{(7-3)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

I_S = Soil ingestion rate (kg dry soil/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

Terrestrial Invertivore (short-tailed shrew)

It was assumed that terrestrial invertivores were exposed by ingestion of terrestrial invertebrates (earthworms) and soil. The equation for exposure of terrestrial invertivores to a single COPEC in contaminated soil by ingestion of terrestrial invertebrates and soil (Ohio EPA 2003) is:

$$ADD_{total} = ADD_A + ADD_S \qquad \textbf{(7-4)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_A = Average daily dose (mg/kgBW/day) from ingestion of animals,
ADD_S = Average daily dose (mg/kgBW/day) from ingestion of soil.

The equation for exposure by ingestion of animals (terrestrial invertebrates) (Ohio EPA 2003) is:

$$ADD_A = RME \times BAF_i \times CF_i \times I_A \times AUF \qquad \textbf{(7-5)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

BAF_i = Soil-to-soil invertebrate BCF [mg/kg dry weight per mg/kg dry soil for inorganic COPECs (= kg dry soil/kg dry weight)],

CF_i = Correction factor (earthworms) [(0.13) for arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, zinc, and PCBs, and is assumed to be 1 for all other COPECs—fraction dry weight worm/kg wet weight],

I_A = Animal ingestion rate (kg fresh animal/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of soil (Ohio EPA 2003) is:

$$ADD_S = RME \times I_S \times AUF \qquad \textbf{(7-6)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

I_S = Soil ingestion rate (kg dry soil/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

Terrestrial Carnivores (red fox and red-tailed hawk)

It was assumed that terrestrial carnivores were exposed by ingestion of small mammals (shrews) and soil. The equation for exposure of terrestrial carnivores by ingestion of animal prey and soil (Ohio EPA 2003) is:

$$ADD_{total} = ADD_P + ADD_A + ADD_S \qquad \textbf{(7-7)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_P = Average daily dose (mg/kgBW/day) from ingestion of plants,
ADD_A = Average daily dose (mg/kgBW/day) from ingestion of animals,
ADD_S = Average daily dose (mg/kgBW/day) from ingestion of soil.

The equation for exposure by ingestion of plants (Ohio EPA 2003) is:

$$ADD_P = RME \times SP_r \times CF \times I_P \times AUF \qquad \textbf{(7-8)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

SP_r = Soil-to-plant BCF [mg/kg dry weight per mg/kg dry soil (= kg dry soil/kg dry weight)]. SP_r indicates a diet of fruit for the fox (hawks are assumed not to consume plant matter),

CF = Correction factor, dry weight to wet weight; assuming 90% water content of fruit, CF = (1 – 0.90) = 0.10,

I_P = Plant ingestion rate (kg fresh plant/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of animals (shrews) (Ohio EPA 2003) is:

$$ADD_A = C_s \times I_A \times AUF \qquad \textbf{(7-9)}$$

where

C_s = Concentration in the prey resulting from RME exposure (mg/kgBW), $C_s = ADD_{total(shrew)} \times BAF_{TP} / IR_{F(shrew)}$

where

BAF_{TP} = Food-to-prey BAF [mg/kgBW of prey per mg/kg food (= kg food/kg BW of prey),

$IR_{F(shrew)}$ = Ingestion rate of food by shrew,

I_A = Animal ingestion rate (kg fresh animal/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of soil (Ohio EPA 2003) is:

$$ADD_S = RME \times I_S \times AUF \qquad \textbf{(7-10)}$$

where

RME = RME concentration of COPECs in soil (mg/kg dry weight),

I_S = Soil ingestion rate (kg dry soil/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

Receptor-specific intake parameters are discussed in Section 7.9.5.2, and chemical-specific BCFs and BAFs are discussed in Section 7.9.5.4.

Benthic Invertebrates

Exposure equations are not needed for benthic invertebrates because the TRV for benthic invertebrates is the concentration in sediment. Therefore, the measure of exposure of benthic invertebrates is the concentration of the COPEC in sediment (mg/kg dry weight).

Riparian Herbivores (muskrat and mallard duck), sediment

Riparian herbivores are exposed to COPECs in sediment by ingestion of food and sediment. It was assumed that their food is rooted aquatic plants that have taken up COPECs from sediment. The equation for exposure of aquatic herbivores to a single COPEC in sediment (Ohio EPA 2003) is:

$$ADD_{total} = ADD_P + ADD_{Sed} \qquad \textbf{(7-11)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_P = Average daily dose (mg/kgBW/day) from ingestion of plants,
ADD_{Sed} = Average daily dose (mg/kgBW/day) from ingestion of sediment.

The equation for exposure by ingestion of plants (Ohio EPA 2003) is:

$$ADD_P = RME \times [0.5 \times (SP_v \times CF_v) + 0.5 \times (SP_r \times CF_r)] \times I_P \times AUF \qquad \textbf{(7-12)}$$

where

RME = RME concentration of COPECs in sediment (mg/kg dry weight),

0.5 = Exposure adjustment factor for a diet of 50% vegetative parts and 50% seeds for mallard ducks (Ohio EPA 2003),

SP_v = Sediment-to-plant BCF [mg/kg dry weight per mg/kg dry sediment (= kg dry sediment/kg dry weight)], SP_v is used for the dietary fraction comprising vegetative plants,

CF_v = Correction factor, dry weight to wet weight; assuming 85% water content of vegetative parts of plants (Ohio EPA 2003), $CF_v = (1 – 0.85) = 0.15$,

SP_r = Sediment-to-plant BCF [mg/kg dry weight per mg/kg dry sediment (= kg dry sediment/kg dry weight)], SP_r is used for the dietary fraction comprising plant seeds,

CF_r = Correction factor, dry weight to wet weight; assuming 10% water content of plant seeds (Ohio EPA 2003), CF = (1 – 0.1) = 0.9,

I_P = Plant ingestion rate (kg fresh plant/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of sediment (Ohio EPA 2003) is:

$$ADD_{Sed} = RME \times I_S \times AUF \qquad \textbf{(7-13)}$$

where

RME = RME concentration of COPECs in sediment (mg/kg dry weight),

I_S = Sediment ingestion rate (kg dry sediment/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

Receptor-specific intake parameters are discussed in Section 7.9.5.2, and chemical-specific BAFs are discussed in Section 7.9.5.4.

Riparian Carnivores (mink and heron), Sediment

Riparian carnivores are exposed to COPECs in sediment by ingestion of food and sediment. It was assumed that their prey is fish at Trophic Level 4. To calculate the concentration of COPECs in prey, a food chain multiplier (FCM, Section 9.5.4) was used, as required by Ohio EPA (2003). The equation for exposure of riparian carnivores to a single COPEC in sediment (Ohio EPA 2003) is:

$$ADD_{total} = ADD_A + ADD_{Sed} \tag{7-14}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_A = Average daily dose (mg/kgBW/day) from ingestion of animals,
ADD_{Sed} = Average daily dose (mg/kgBW/day) from ingestion of sediment.

The equation for exposure by ingestion of animals (fish) (Ohio EPA 2003) is:

$$ADD_A = RME \times BSAF \times FCM \times I_A \times AUF \tag{7-15}$$

where

RME = RME concentration of COPECs in sediment (mg/kg dry weight),

BSAF = Sediment-to-benthic invertebrate BAF [mg/kgBW of benthic invertebrate per mg/kg dry sediment (= kg dry sediment/kgBW)],

FCM = Food-chain multiplier, 1.0 for inorganic COPECs and chemical-specific for organic COPECs (Ohio EPA 2003) (see Section 7.9.5.4),

I_A = Fish ingestion rate (kg wet weight/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of sediment (Ohio EPA 2003) is:

$$ADD_{Sed} = RME \times I_S \times AUF \tag{7-16}$$

where

RME = RME concentration of COPECs in sediment (mg/kg dry weight),

I_S = Sediment ingestion rate (kg dry sediment/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

Receptor-specific intake parameters are discussed in Section 7.9.5.2, and chemical-specific BAFs are discussed in Section 7.9.5.4.

Aquatic Biota

Exposure equations are not needed for aquatic biota because the TRV for aquatic biota is the concentration in surface water. Therefore, the measure of exposure of aquatic biota is the concentration of the COPEC in surface water at the EU (mg/L).

Riparian Herbivores (muskrat and mallard), Water

It was assumed that riparian herbivores are exposed to COPECs in surface water by ingestion of food and water. It was assumed that their food is floating aquatic plants that have taken up COPECs from surface water. The equation for exposure of aquatic herbivores to a single COPEC in surface water (Ohio EPA 2003) is:

$$ADD_{total} = ADD_P + ADD_W \quad \textbf{(7-17)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,
ADD_P = Average daily dose (mg/kgBW/day) from ingestion of plants,
ADD_W = Average daily dose (mg/kgBW/day) from ingestion of surface water.

The equation for exposure by ingestion of plants (Ohio EPA 2003) is:

$$ADD_P = RME \times WP \times I_P \times AUF \quad \textbf{(7-18)}$$

where

RME = RME concentration of COPECs in surface water (mg/L),

WP = Water-to-plant BCF [mg/kg wet weight per mg/L (= L/kg wet weight)],

I_P = Plant ingestion rate (kg fresh plant/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of surface water (Ohio EPA 2003) is:

$$ADD_W = RME \times IR_W \times AUF \quad \textbf{(7-19)}$$

where

RME = RME concentration of COPECs in surface water (mg/L),

IR_W = Water ingestion rate (L/kgBW/day),

AUF = Area use factor, ratio of an organism’s home range to the area of contamination (see Section 7.9.5.4).

Receptor-specific intake parameters are discussed in Section 7.9.5.2, and chemical-specific BAFs are discussed in Section 7.9.5.4.

Riparian Carnivores (mink and heron), Water

Riparian carnivores are exposed to COPECs in surface water by ingestion of food and water. It was assumed that their food is fish at Trophic Level 4. To calculate the concentration of COPECs in prey, an FCM (Section 9.5.4) was used, as required by Ohio EPA (2003). The equation for exposure of riparian carnivores to a single COPEC in contaminated surface water (Ohio EPA 2003) is:

$$ADD_{total} = ADD_{A} + ADD_{SW} \qquad \textbf{(7-20)}$$

where

ADD_{total} = Average daily dose (mg/kgBW/day) from all ingestion combined,

ADD_{A} = Average daily dose (mg/kgBW/day) from ingestion of aquatic animals (assumed to be fish at Trophic Level 4),

ADD_{SW} = Average daily dose (mg/kgBW/day) from ingestion of surface water.

The equation for exposure by ingestion of aquatic animals (Ohio EPA 2003) is:

$$ADD_{A} = RME \times BAF_{aq} \times I_{A} \times AUF \qquad \textbf{(7-21)}$$

where

RME = Concentration of COPECd in surface water (mg/L),

BAF_{aq} = Water-to-aquatic biota BAF for prey [mg/kg wet weight per mg/L surface water (=L surface water/kg fresh tissue)],

I_{A} = Animal intake (kg fresh animal/kg body weight-day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

The equation for exposure by ingestion of surface water (Ohio EPA 2003) is:

$$ADD_{SW} = RME \times IR_{W} \times AUF \qquad \textbf{(7-22)}$$

where

RME = RME concentration of COPECs in surface water (mg/L),

IR_{W} = Water ingestion rate (L/kgBW/day),

AUF = Area use factor, ratio of an organism's home range to the area of contamination (see Section 7.9.5.4).

Receptor-specific intake parameters are discussed in Section 7.9.5.2, and chemical-specific BCFs and BAFs are discussed in Section 7.9.5.4.

7.9.5.4 Uptake factors (BCFs and BAFs) and other factors

For some COPECs the BCF and BAF values used in the ADD equations are available in guidance or other published literature. For some COPECs these values must be estimated. The order of preference (Ohio EPA 2003) for use of BCFs and BAFs is: (1) government agency guidance; (2) published values in the open scientific literature; and (3) calculations based on chemical properties. BCFs and BAFs can be estimated using chemical properties of the COPECs such as the logarithm of the octanol-water partitioning coefficient [$\log(K_{ow})$] and the soil-to-water partitioning coefficient (K_d). Chemical-specific BCFs and BAFs for terrestrial plants, terrestrial invertebrates, mammals, and birds are presented in Table O-21. Chemical-specific BCFs and BAFs for aquatic plants, benthic invertebrates, and fish are presented in Table O-22. Receptor-specific parameters were also needed to calculate some BAFs when empirically derived factors were not available. Receptor-specific parameters are presented in Section 7.9.5.2 and in Tables O-13 through O-20.

BCFs for Terrestrial Plants (SP_V and SP_r)

Chemical concentrations in terrestrial plants were calculated by using factors for uptake from soil into the aboveground portion of plants. The concentration in aboveground vegetative and reproductive portions of plants through root uptake from soil is a function of the chemical-specific soil concentration and chemical-specific plant BCFs (SP_v for vegetative portions and SP_r for reproductive portions).

Empirically determined SP_vs and SP_rs were used in preference to calculated or estimated values. Default values were not used if values based on chemical properties were available.

As specified by Ohio EPA (2003), SP_vs and SP_rs for inorganic COPECs were taken from Baes et al. (1984). SP_vs for some organic COPECs were taken from EPA (1999c). For organic COPECs with no published values, SP_vs were calculated using an equation developed by Travis and Arms (1988). The equation is:

$$\log(SP_v) = 1.588 - 0.578 \times \log(K_{ow}) \qquad \textbf{(7-23)}$$

where

SP_v = soil-to-plant BCF (kg dry soil/kg plant or g dry soil/g plant), and
K_{ow} = octanol-water partitioning coefficient (L/kg).

Values of SP_v, SP_r, and $\log(K_{ow})$ are given in Table O-21.

BAFs for Terrestrial Invertebrates (BAF-S)

Chemical concentrations in terrestrial invertebrates were calculated using uptake factors from soil into the invertebrate tissue. The concentration accumulated in invertebrate tissues through direct contact with and ingestion of soil and detritus is a function of the chemical-specific soil concentration and chemical-specific invertebrate BAF-S.

There are few published BAFs for uptake of COPECs from soil by terrestrial invertebrates. Measured values for arsenic, cadmium, chromium, lead, manganese, mercury, nickel, and zinc (Sample et al. 1999) were used and are included in Table O-21. Additional values for inorganics were taken from EPA (1999c). Following EPA (1999c) guidance, BAF-S values for other inorganic COPECs were calculated as the average of available measured values (e.g., Sample et al. 1999).

For organic COPECs that have no published values, default values were calculated using the following equation (Ohio EPA 2003):

$$\text{BAF-S} = (yL/x \times f_{oc}) \times (K_{ow})^{b-a} \qquad \textbf{(7-24)}$$

where

BAF-S = Soil-to-terrestrial invertebrate BAF (kg dry soil/kg fresh invertebrate),

yL = Organic lipid content [default value of 0.01 for earthworm (Ohio EPA 2003)], (kg lipid/kg fresh invertebrate),

x = Proportionality constant [0.66 (Ohio EPA 2003)],

f_{oc} = Fraction of organic carbon in soil, 0.01 (kg carbon/kg dry soil),

K_{ow} = Octanol-water partitioning coefficient (L/kg),

b-a = Non-linearity constant [0.07 (Ohio EPA 2003)].

The value of 0.01 for f_{oc} was the geometric mean of f_{oc} for soil EUs. These values are included in Table O-21.

BAFs for Terrestrial Mammals (BAF_{TP})

Published soil-to-animal BAFs are predominantly available only for terrestrial invertebrates. Ohio EPA (2003) guidance states that ingestion-to-beef uptake factors (B_a) presented by Baes et al. (1984) are to be used as BAFs to calculate the uptake of inorganic COPECs by mammals and birds.

The units of B_a are (mg retained/kg tissue)/(mg ingested/day). This value is a measure of the fraction of each day's intake of a COPEC in beef that is retained in tissue. Ohio EPA (2003) guidance assumes that the fraction of COPECs that is retained is the same for mammals and birds and does not vary with body weight. To calculate the BAF for mammal or bird receptors (BAF_{TP}), B_a was multiplied by the body weight of the receptor to put the uptake factor in terms of total ingestion of COPEC per day. That is,

$$BAF_{TP} = Ba \times BW, \qquad \textbf{(7-25)}$$

where

BAF_{TP} = BAF for mammal or bird receptor [mg retained / (mg ingested/day)],

Ba = Ingestion-to-beef transfer factor [(mg retained/kg tissue)/(mg ingested/day) (Baes et al. 1984)],

BW = Body weight of receptor (kg).

Values of B_a and BAF_{TP} are given in Table O-21.

BCFs for Aquatic Plants Rooted in Sediment

Aquatic plants rooted in sediment were assumed to have the same BCFs for vegetative and reproductive parts as for terrestrial plants (SP_V and SP_r, respectively). SP_Vs and SP_rs for inorganic COPECs were taken from EPA (1999c) and Baes et al. (1984) and are provided in Table O-21. SP_rs for organic COPECs were assumed to be the same as SP_Vs.

BAFs for Benthic Invertebrates (BSAF)

There are few published BSAF values for uptake of COPECs from sediment. BSAFs from EPA (1999c) were used for inorganic and organic COPECs when values were available in that reference. For inorganic COPECs without published values, the value proposed by EPA (1999c), which was the arithmetic mean of all available values for inorganics, was 0.9. For organic COPECs without published values, the BSAFs were calculated by using the equation for terrestrial invertebrates (Section 7.9.5.4). The value of foc was 0.01, the measured value in Kelly's Pond. These values are included in Table O-22.

BCFs for Floating Aquatic Plants (WP)

Floating aquatic plants were assumed to take up COPECs from water. The BCFs for water-to-plant bioaccumulation are termed WP. Values of WP for inorganic COPECs were taken from EPA (1999c). Values of WP for organic COPECs were calculated by an empirically derived equation for uptake from water by algae (Southworth et al. 1978). The equation is:

$$\log(WP) = 0.819 \times \log(K_{ow}) - 1.146.$$

BAFs for Aquatic Animals (BAFaq)

Chemical concentrations in aquatic biota were calculated using factors for uptake from surface water into the tissue of aquatic biota. The concentration in aquatic macroinvertebrates through uptake from surface water is a function of the chemical-specific surface water concentration and chemical-specific BCFs. It was assumed that organic COPECs can bioaccumulate up the food chain. To calculate a BAFaq for an organic COPEC, the BCF is multiplied by the FCM for that COPEC. The hierarchy of sources for BAFs (Ohio EPA 2003) used in the screening level ERA was: (1) field-measured BAFs; (2) predicted BAFs derived by multiplying a laboratory-measured BCF by an FCM (EPA 1995); and (3) predicted BAFs derived by multiplying a BCF calculated from the K_{ow} by an FCM (EPA 1995).

Published BCFaq values for aquatic animals are presented in Table O-22. Measured values for mercury and nickel were taken from EPA (1999c). For organic COPECs that have no published BCFaq, the following equation (EPA 1999c) was used to estimate the BCF:

$$\log(BCF_{aq}) = 0.91 \times \log(K_{ow}) - 1.975 \times \log[(6.8E\text{-}07 \times K_{ow}) + 1] - 0.786 \qquad \textbf{(7-26)}$$

where

BCF_{aq} = Water-to-aquatic biota BCF [mg/kg fresh tissue per mg/L (= L/kg)],
K_{ow} = Octanol-water partitioning coefficient.

Calculated BCFaq values are also presented in Table O-22.

BAFaq is calculated by using FCMs that account for bioaccumulation of COPECs through the food chain (EPA 1995). BAFaq is calculated as:

$$BAF_{aq} = BCF \times FCM \qquad \textbf{(7-27)}$$

where

BCF = Water-to-tissue BCF (L/kg body wt),
FCM = Food-chain multiplier (unitless). FCMs specific to Trophic Level 4 are assumed.

7.9.5.5 FCMs

FCMs are factors that are used to quantify bioaccumulation through the food chain. As chemicals from the environment pass up the food chain, they may become successively more concentrated at each trophic level. This is especially true of organic chemicals that are not metabolized rapidly. Typically, organic chemicals that dissolve in lipids bioaccumulate because they are stored in body fat, and the more soluble in lipids the chemical is, the more it bioaccumulates. To model this tendency quantitatively, EPA (1995) measured BAFs for organic chemicals taken up through the food chain from water by fish. An FCM was derived for each chemical tested by dividing the observed BAF by the K_{ow}. EPA (1995) was able to show an orderly relationship between FCM and K_{ow} for many organic chemicals taken up by fish at Trophic Levels 2, 3, and 4. By using this relationship, the concentration of a chemical in fish tissue, normalized to lipid content, can be calculated by multiplying the concentration of the chemical dissolved in water by the BCF of the chemical and by the chemical's FCM.

The FCM for inorganic COPECs is 1.0 (EPA 1995). The FCMs used for organic COPECs were those for Trophic Level 4 and are presented in Table O-22.

7.9.5.6 AUFs

Ecological receptors typically forage over a receptor-specific area termed the home range. Home ranges for many species of animals are available in published literature and compendia. It was assumed that receptors at EBG forage uniformly over a home range that includes the EU. The fraction of the ingestion exposure that comes from the EU is termed the AUF. For receptors with a home range larger than the EU, AUF is calculated as the area of the EU divided by the home range. For receptors with a home range smaller than the EU, such as the short-tailed shrew and muskrat, AUF is 1.0. AUFs for receptors exposed to COPECs in soil are shown in Table O-23, and AUFs for receptors exposed to COPECs in sediment and surface water are shown in Table O-24.

7.9.5.7 Ingestion rates

Exposure equations require ingestion rates of plants (I_P), soil (I_S), animal tissue (I_A), sediment (I_S), and surface water (IR_W). These values are shown in the receptor parameter tables (Tables O-13 through O-20) and are summarized in Table O-25.

7.9.6 Effects Evaluation for Chemicals of Potential Ecological Concern

Measures of toxicity were used as endpoints to compute HQs. Toxicity endpoints, termed TRVs, were derived from published studies of exposure to contaminants under controlled conditions. TRVs were used for exposure of terrestrial plants, terrestrial invertebrates, terrestrial mammals, terrestrial birds, benthic invertebrates, riparian mammals, riparian birds, and aquatic biota.

7.9.6.1 Terrestrial plants and invertebrates

Toxicity endpoints for plants and terrestrial invertebrates were taken from Efroymson et al. (1997c) and Efroymson et al. (1997b), respectively (Ohio EPA 2003). These values are generally the LOAEL or the lower 5th percentile concentration for adverse effects for plants and earthworms exposed to soil amended with chemicals. TRVs for terrestrial plants are shown in Table O-26, and TRVs for terrestrial invertebrates are shown in Table O-27.

7.9.6.2 Terrestrial mammals and birds

The preferred endpoint for mammals and birds is a chronic NOAEL for a measure of population maintenance, such as reproduction. If a chronic NOAEL is not available, a substitute can be computed using one of the following procedures (Ohio EPA 2003).

- Divide a subchronic NOAEL for longer-term subchronic exposures by 3.
- Divide a subchronic NOAEL for sub-acute or short-term subchronic exposures by 10.
- Divide an acute NOAEL by 100.
- Divide a chronic LOAEL for a reproductive endpoint or a minor physiological change by 3.
- Divide a chronic LOAEL for an effect that would reduce survivability in the wild or a gross or severe physiological change by 10.
- Divide a subchronic LOAEL for longer-term subchronic exposure by 3 to convert to a chronic LOAEL, then divide by 3 or 10 to convert to a chronic NOAEL, as indicated in the third and fourth bullets.
- Divide a subchronic LOAEL for sub-acute or short-term subchronic exposure by 10 to convert to a chronic LOAEL, then divide by 3 or 10 to convert to a chronic NOAEL, as indicated in the third and fourth bullets.
- Divide an acute LOAEL by 1,000.
- Divide an LD_{50} by 10,000.

Chronic NOAELs for mammals, or their calculated equivalents, are shown in Table O-28. A TRV was calculated for each mammal by using allometric scaling to account for differences in toxicity related to body weight (Ohio EPA 2003). The equation used for this adjustment is:

$$\text{TRV} = \text{chronic NOAEL} \times (BW_t / BW_w)^{1/4} \qquad \textbf{(7-28)}$$

where

TRV = Toxicity reference value (mg/kg body wt-day),
BW_t = Body weight of the species used in toxicity testing (kg),
BW_w = Body weight of the wildlife species (kg),
1/4 = Allometric scaling factor for mammals.

These adjusted values were used as TRVs for the computation of HQs for mammals and are shown in Table O-29.

Chronic NOAELs for birds, or their calculated equivalents, are shown in Table O-30. Body weight scaling was not conducted for birds (Ohio EPA 2003). Instead, an adjustment was based on the taxonomic distance between the test species and the ecological receptor, as follows.

- If the test species and the ecological receptor were in the same genus, no adjustment was made.

- If the test species and the ecological receptor were in the same family but not the same genus, the chronic NOAEL was multiplied by one-half order of magnitude (0.33).

- If the test species and the ecological receptor were in the same order but not the same family, the chronic NOAEL was multiplied by 0.1.

- If the test species and the ecological receptor were not in the same order, the chronic NOAEL was multiplied by 0.01.

TRVs for birds are shown in Table O-31.

7.9.6.3 Benthic invertebrates

The Ohio EPA (2003) hierarchy of TRVs for benthic invertebrates is the same as the hierarchy for TRVs (Ohio EPA 2003): (1) consensus-based TEC values (MacDonald, Ingersoll, and Berger 2000) and (2) *EPA Region 5 Corrective Action, Ecological Screening Levels* (EPA 2003b), which can be found at URL http://www.epa.gov/reg5rcra/ca/edql.htm. TRVs for benthic invertebrates are presented in Table O-32.

7.9.6.4 Aquatic biota

The Ohio EPA (2003) hierarchy of TRVs for aquatic biota is: (1) Ohio water quality criteria (Ohio EPA 2003); (2) National Ambient Water Quality Criteria (found in Suter and Tsao 1996), Tier II values (found in Suter and Tsao 1996), and other toxicity values presented in Suter and Tsao (1996). TRVs for aquatic biota are intended to protect most aquatic species from harm by chronic exposure most of the time. TRVs for aquatic biota are shown in Table O-33.

7.9.6.5 Riparian mammals and birds

TRVs for riparian mammals and birds were computed as described for terrestrial mammals and birds. The TRVs are shown in Tables O-29 (mammals) and O-31 (birds).

7.9.6.6 Summary of methods

The Level III exposure and toxicity evaluation used an estimate of the RME concentrations in environmental media at each EU to identify COPECs and ecological receptors that require no further analysis. Internal concentrations of COPECs in plants, terrestrial invertebrates, benthic invertebrates, terrestrial prey, aquatic plants, aquatic biota, and fish were calculated and used to calculate ADDs to terrestrial herbivores, terrestrial invertivores, terrestrial carnivores, riparian herbivores, and riparian carnivores. Calculation of receptor-specific ADDs requires parameters that describe the home range, body weight, food and water intake rates, and diet distribution. Receptor parameters were compiled for the representative receptors for the Level III BERA.

Relationships and equations used to calculate exposure to COPECs were adapted from equations presented in Ohio EPA guidance (Ohio EPA 2003). Equations are given here for

- terrestrial plants exposed by direct contact with soil,

- terrestrial invertebrates exposed by direct contact with soil,

- terrestrial mammals and birds (e.g., rabbit, shrew, fox, and hawk) exposed to COPECs by ingestion of food and soil,
- benthic invertebrates (aquatic insect larvae, crayfish, snails, clams, and bivalves) exposed by direct contact with sediment,
- aquatic biota (aquatic invertebrates and fish) exposed by direct contact with water,
- riparian herbivores (muskrat and mallard) exposed by ingestion of food and sediment or surface water, and
- riparian carnivores (mink and heron) exposed by ingestion of food and sediment or surface water.

The BCFs and BAFs needed to parameterize bioconcentration and bioaccumulation were compiled and used in the exposure equations.

Measures of toxicity were used as endpoints to compute HQs. Toxicity endpoints, termed TRVs, were used for exposure of ecological receptors to COPECs in soil, sediment, and surface water. For direct exposure (terrestrial plants, terrestrial invertebrates, aquatic biota, and benthic invertebrates), the HQ was calculated by dividing the RME concentration in soil, surface water, or sediment by the TRV. The HQs for ingestion exposures were calculated by dividing the ADD by the TRV.

7.10 RESULTS OF LEVEL III HAZARD QUOTIENT CALCULATIONS FOR CHEMICALS OF ECOLOGICAL CONCERN

HQ calculation tables for all of the ecological receptors are presented in Appendix Tables O-34 through O-53. The HQ calculation tables are organized by media, EU, and receptor within each EU. This section will not discuss in detail each of the HQs for each receptor, but briefly summarizes (1) contaminants that qualify for NFA due to HQs = 1 for all receptors applicable for the given media, (2) COECs due to HQs > 1 for one or more receptors, and (3) COECs of uncertain risk due to “no TRVs” for one or more receptors. Note that COECs based on “No TRV” had three possible conditions: (1) one or more receptors did have a TRV and an HQ > 1, (2) one or more receptors had a TRV but the HQs were = 1, or (3) all of the receptors had “No TRV,” which are identified in Table 7-8. The results of HQ calculations and subsequent summary of NFA analytes and COECs for surface soil (0 to 1 ft), subsurface soil, sediment, and surface water are discussed in Sections 7.10.1, 7.10.2, 7.10.3, and 7.10.4, respectively.

7.10.1 Surface Soil Receptor Hazard Quotients

HQs were calculated for terrestrial receptors exposed to surface soil at the one EU and are discussed below.

Twenty inorganic, 4 explosive, and 16 SVOC surface soil COPECs were inputted for HQ calculations for plants and earthworms, cottontail rabbits, and shrews, which are presented in Tables O-34, O-35, and O-36, respectively. For foxes and red-tailed hawks, 4 inorganic and 16 SVOC PBT COPECs were inputted for HQ calculations, which are presented in Tables O-37 and O-38, respectively.

Surface soil NFAs. Three inorganics (cadmium, mercury, and nickel) were the only inputted COPECs for surface soil that qualified for NFA following the BERA HQ calculations because their HQs were less than 1 for all the terrestrial receptors.

Table 7-8. Summary of COECs for Erie Burning Ground Media

COEC	Surface Soil		Subsurface Soil		Sediment		Surface Water	
COECs per HQ > 1								
Inorganics								
Aluminum	Plant	266	NA		Muskrat	3.0	Aq Biota	34
	Rabbit	221			--		Muskrat	9,550
	Shrew	842					Duck	3.3
Antimony	Plant	1.6	Rabbit	1.2	Muskrat	28	NA	
	Rabbit	2.9	Shrew	3.2	--			
	Shrew	7.9	--					
Arsenic	Plant	1.1	NA		Sed Biota	1.4	NA	
	Rabbit	3.0			--			
	Shrew	3.8						
Barium	Rabbit	1.1	NA		*		Aq Biota	3.5
	Shrew	3.1					Muskrat	15
Cadmium	No HQ > 1		No HQ > 1		Sed Biota	3.6	Aq Biota	1.6
					Heron	149	Muskrat	1.3
					--		Heron	45
Chromium	Plant	23	NA		NA		NA	
	Worm	57						
Copper	Worm	1.4	No HQ > 1		Sed Biota	4.7	Aq Biota	68
Cyanide	*		NA		Sed Biota	10,100	Aq Biota	2.2
Iron	Plant	2,500	NA		*		Aq Biota	127
Lead	Plant	3.3	No HQ > 1		Sed Biota	6.7	Aq Biota	17
	Shrew	2.4			Heron	2,410	Muskrat	9.6
	--				--		Duck	2.5
Manganese	Plant	1.6	NA		*		Aq Biota	83
	--						Muskrat	186
Mercury	No HQ > 1		No HQ > 1		No HQ > 1		Heron	17
Nickel	No HQ > 1		NA		Sed Biota	1.5	NA	
Silver	*		NA		Sed Biota	3.7	NA	
					--			
Vanadium	Plant	10	NA		*		NA	
	Shrew	9.4						
Zinc	Plant	11	Plant	2.4	Sed Biota	12	Aq Biota	6.6
	Worm	2.9	--		Heron	1,040	Muskrat	4.4
	--				--		Duck	1.8
							Heron	2,020
Explosives								
2,6-DNT	NA		NA		Sed Biota	4.0	NA	
Pesticides/PCBs								
PCB-1254	NA		NA		Heron	102	NA	
Semivolatiles								
Benzo(*a*)anthracene	*		*		Sed Biota	2.5	NA	
					Heron	8,920		
Benzo(*a*)pyrene					Sed Biota	2.5	NA	
	*		*		Heron	191		
Benzo(*k*)fluoranthene	*		*		Sed Biota	1.5	NA	

Table 7-8. Summary of COECs for Erie Burning Ground Media (continued)

COEC	Surface Soil	Subsurface Soil	Sediment		Surface Water
BEHP	*	*	Sed Biota	3.5	NA
			Heron	53,900	
Chrysene	*	*	Sed Biota	3.9	NA
			Heron	1,600	
Fluoranthene	*	*	Sed Biota	1.6	NA
Fluorene	NA	NA	Sed Biota	3.1	NA
Indeno(1,2,3-*cd*)pyrene	*	*	Sed Biota	1.4	NA
			Heron	2,190	
Phenanthrene	*	*	Sed Biota	3.3	NA
Pyrene	*	*	Sed Biota	3.4	NA
Volatiles					
Acetone	NA	NA	Sed Biota	7.7	NA
COECs per No TRV					
Inorganics					
Aluminum	No TRV[a]	NA	No TRV[a]		**
Antimony	No TRV[a]	No TRV[a]	No TRV[a]		NA
Barium	No TRV[a]	NA	No TRV[b]		**
Beryllium	NA	NA	No TRV[b]		NA
Calcium	No TRV[c]	NA	No TRV[c]		No TRV[b]
Cyanide	No TRV[c]	NA	No TRV[b]		No TRV[a]
Iron	No TRV[a]	NA	No TRV[c]		No TRV[a]
Magnesium	No TRV[c]	NA	No TRV[c]		No TRV[b]
Manganese	No TRV[a]	NA	No TRV[b]		**
Potassium	No TRV[c]	NA	NA		No TRV[b]
Silver	No TRV[b]	NA	No TRV[a]		NA
Sodium	No TRV[c]	No TRV[c]	No TRV[c]		No TRV[c]
Vanadium	No TRV[a]	NA	No TRV[b]		NA
Pesticides/PCBs					
PCB-1254	NA	NA	No TRV[b]		NA
Methoxyclor	No TRV[c]	NA	No TRV[b]		NA
Volatiles					
Acetone	NA	NA	No TRV[a]		No TRV[b]
2-Butanone	NA	NA	No TRV[b]		NA
Chloromethane	NA	NA	NA		No TRV[c]
Semivolatiles					
Acenaphthylene	No TRV[c]	NA	NA		NA
Anthracene	No TRV[c]	NA	NA		NA
Benzo(*a*)anthracene	No TRV[c]	No TRV[c]	No TRV[a]		NA
Benzo(*a*)pyrene	No TRV[b]	No TRV[b]	**		NA
Benzo(*b*)fluoranthene	No TRV[c]	No TRV[c]	No TRV[b]		NA
Benzo(*g,h,i*)perylene	No TRV[c]	NA	No TRV[b]		NA
Benzo(*k*)fluoranthene	No TRV[c]	No TRV[c]	No TRV[a]		NA
Bis(2-ethylhexyl)phthalate	No TRV[b]	No TRV[b]	No TRV[a]		NA
Butylbenzylphthalate	NA	NA	No TRV[b]		NA
Carbazole	No TRV[c]	NA	No TRV[c]		NA
Chrysene	No TRV[c]	No TRV[c]	No TRV[b]		NA
Dibenzo(*a,h*)anthracene	No TRV[c]	NA	No TRV[b]		NA
Fluoranthene	No TRV[c]	No TRV[c]	No TRV[a]		NA
Fluorene	NA	NA	No TRV[a]		NA

Table 7-8. Summary of COECs for Erie Burning Ground Media (continued)

COEC	Surface Soil	Subsurface Soil	Sediment	Surface Water
Indeno(1,2,3-*cd*)pyrene	No TRV[c]	No TRV[c]	No TRV[a]	NA
Naphthalene	No TRV[b]	NA	NA	NA
N-nitrosodiphenylamine	NA	NA	No TRV[c]	NA
Phenanthrene	No TRV[c]	No TRV[c]	No TRV[a]	NA
Pyrene	No TRV[c]	No TRV[c]	No TRV[a]	NA
Explosives				
2-Amino-4,6-DNT	No TRV[c]	NA	NA	NA
4-Amino-2,6-DNT	No TRV[c]	NA	NA	NA
2,4,6-Trinitrotoluene	NA	NA	No TRV[b]	NA
2,6-DNT	NA	NA	No TRV[a]	NA
Nitrobenzene	NA	NA	No TRV[b]	NA
Nitrocellulose	No TRV[c]	No TRV[c]	No TRV[c]	No TRV[c]
4-Nitrotoluene	No TRV[c]	NA	NA	NA

[a] HQ > 1 for one or more receptors (see above).
[b] HQ > 1 for no receptors.
[c] No TRVs for all receptors.
*COEC because no toxicity reference values for one or more contaminant (see below).
**COEC because HQ > 1 for one or more contaminant (see above).
BEHP = bis(2-ethylhexyl)phthalate.
COEC = Chemical of ecological concern.
DNT = Dinitrotoluene.
HQ = Hazard quotient.
NA = Not applicable because contaminant is not a contaminant of preliminary ecological concern at this location.
PCB = Polychlorinated biphenyl.
-- = All other receptor HQs < 1 for this location.

Surface soil COECs per Erie Burning Ground HQs > 1. Erie Burning Ground HQs exceeding 1 for the six terrestrial receptors are summarized in Table 7-8.

For plants, nine inorganics (aluminum, antimony, arsenic, chromium, iron, lead, manganese, vanadium, and zinc) were surface soil COECs due to EBG HQs > 1, with iron being highest (HQ = 2,500) followed by aluminum (HQ = 266). For earthworms, chromium, copper, and zinc were the only COECs based on an EBG HQ > 1, with chromium being highest (HQ = 57).

For cottontail rabbits, five inorganics (aluminum, antimony, arsenic, barium, and vanadium) were surface soil COECs due to EBG HQs > 1, with aluminum having the highest HQ (HQ = 221) followed by antimony and arsenic (HQ = 3). For shrews, six inorganics (aluminum, antimony, arsenic, barium, lead, and vanadium) were the COECs whose EBG HQs > 1. For shrews, aluminum had the highest HQ (842), followed by vanadium (HQ = 9.4).

For foxes and hawks, there were no EBG HQs > 1 for surface soil.

Surface soil COECs per "No TRV." Twelve inorganics (aluminum, antimony, barium, calcium, cyanide, iron, magnesium, manganese, potassium, silver, sodium, and vanadium), 1 pesticide (methozychlor), 16 SVOCs, and 4 explosives PCB were the 32 soil COECs based on no TRV for at least one terrestrial receptor at this EU (Table 7-8). Note that 6 (all inorganics) of the 32 COECs based on "No TRV" were also COECs based on an EBG HQ > 1 for at least one receptor.

7.10.2 Ground Subsurface Soil Receptor Hazard Quotients

HQs were calculated for terrestrial receptors exposed to subsurface soil at the one EU and are discussed below.

Seven inorganic, one explosive, and ten SVOC subsurface soil COPECs were inputted for HQ calculations for plants and earthworms, cottontail rabbits, and shrews, which are presented in Tables O-39, O-40, and O-41, respectively. For foxes and red-tailed hawks, four inorganic and ten SVOC PBT COPECs were inputted for HQ calculations, which are presented in Tables O-42 and O-43, respectively.

Subsurface soil NFAs. Four inorganics (cadmium, copper, lead, and mercury) were the only inputted COPECs for subsurface soil that qualified for NFA following the BERA HQ calculations because their HQs were less than 1 for all the terrestrial receptors.

Subsurface soil COECs per Erie Burning Ground HQs > 1. EBG HQs exceeding 1 for the six terrestrial receptors are summarized in Table 7-8.

For plants, one inorganic (zinc) was the only subsurface soil COEC due to an EBG HQ > 1 (HQ = 2.4). For earthworms, there were no HQs > 1 for subsurface soil.

For cottontail rabbits, one inorganic (antimony) was the only subsurface soil COEC due to EBG HQs > 1 (HQ = 1.2). For shrews, antimony also was the only COEC whose EBG HQs > 1 (HQ = 3.2).

For foxes and hawks, there were no Erie Burning Ground HQs > 1 for subsurface soil.

Subsurface soil COECs per "No TRV." Two inorganics (antimony and sodium), 10 SVOCs, and 1 explosive (nitrocellulose) were the 13 soil COECs based on no TRV for at least one terrestrial receptor at this EU (Table 7-8). Note that 1 of the 13 COECs (antimony) based on "No TRV" was also a COEC based on an EBG HQ > 1 for at least one receptor.

7.10.3 Sediment Receptor Hazard Quotients

HQs were calculated for sediment receptors exposed to surface sediment at the single EU, and are discussed below.

Twenty inorganic, 4 explosive, 2 pesticide/PCB, 16 SVOC, and 2 VOC COPECs for sediment were inputted for HQ calculations for sediment biota, muskrats, and mallards, which are presented in Tables O-44, O-45, and O-46, respectively. For mink and Great blue herons, 4 inorganic, 2 pesticide/PCB, and 16 SVOC PBT COPECs were inputted for HQ calculations, which are presented in Tables O-47 and O-48, respectively.

Sediment NFAs. Mercury was the only inputted COPEC that qualified for NFA for sediment following the BERA HQ calculations because it had no HQs > 1 for any aquatic receptors.

Sediment COECs per HQs > 1. HQs exceeding 1 for these five receptors are summarized in Table 7-8.

For sediment biota, eight inorganics (arsenic, cadmium, copper, cyanide, lead, nickel, silver, and zinc), one PCB (PCB-1254), one explosive (2,6-DNT), and ten SVOCs were the sediment COECs due to EBG HQs > 1. The highest HQ was for cyanide (HQ = 10,100) followed by zinc (HQ = 12).

For muskrats, two inorganics (aluminum and antimony) were the only sediment COECs due to EBG HQs > 1 (HQs = 28 and 3, respectively). For mallards, no HQs exceeded 1.

For mink, no HQs exceeded 1. However, for Great blue herons, three inorganics (cadmium, lead, and zinc), one PCB (PCB-1254), and five SVOCs were COECs based on an HQ > 1. The highest HQ was for bis(2-ethylhexyl)phthalate (HQ = 53,900) followed by benzo(*a*)anthracene (HQ = 8,920).

Sediment COECs per "No TRV." Twelve inorganics (aluminum, antimony, barium, beryllium, calcium, cyanide, iron, magnesium, manganese, silver, sodium, and vanadium), 2 pesticides/PCBs, (PCB-1254 and methoxychlor), 4 explosives, 15 SVOCs, and 2 VOCs were the 35 COECs for sediment based on no TRV for at least one receptor. Five of the COECs (four inorganics and PCB-1254) based on "No TRV" were also COECs based on an EBG HQ > 1 for at least one receptor.

7.10.4 Surface Water Receptor Hazard Quotients

HQs were calculated for surface water receptors exposed to surface water at the one EU and are discussed below.

Fourteen inorganic, one explosive, and two VOC COPECs for surface water were inputted for HQ calculations for aquatic biota, muskrats, and mallards, which are presented in Tables O-49, O-50, and O-51, respectively. There were four inorganic PBT COPECs for surface water inputted for HQ calculations for mink and herons, which are presented in Tables O-52 and O-53, respectively.

Surface Water NFAs. None of the inputted COPECs for surface water qualified for NFA following the BERA HQ calculations because they all either had at least one receptor with an HQ > 1 or they had no TRV.

Surface Water COECs per HQs > 1. HQs exceeding 1 are summarized in Table 7-8.

For aquatic biota, nine inorganics (aluminum, barium, cadmium, copper, cyanide, iron, lead, manganese, and zinc) were the COECs based on HQs > 1, with manganese being highest (HQ = 83), followed by copper (HQ = 68).

For muskrats, six inorganics (aluminum, barium, cadmium, lead, manganese, and zinc) were the COECs based on HQs > 1, with aluminum being highest (HQ = 9,550) followed by manganese (HQ = 186). For mallards, three inorganics (aluminum, lead, and zinc) were COECs based on HQs > 1, with aluminum being highest (HQ = 3.3).

For mink, there were no HQs > 1. However, for herons, three inorganics (cadmium, mercury, and zinc) were COECs based on HQs > 1, with zinc being highest (HQ = 2,020), followed by cadmium (HQ = 44).

Surface Water COECs per "No TRV." Six inorganics (calcium, cyanide, iron, magnesium, potassium, and sodium), one explosive (nitrocellulose), and two VOCs (acetone and chloromethane) were surface water COECs based on "No TRV" for one or more aquatic receptors. Two of those 9 COECs (cyanide and iron) were also a COEC based on an HQ > 1 for at least one receptor.

7.10.5 Future Risk to Ecological Receptors

The current HQs for the terrestrial plants and animals at the EBG EUs are assumed to be the same or similar to future HQs because most of the soil COEC concentrations are not expected to change dramatically over time, assuming there are no disturbances to the soil. For example, most inorganic

COECs like the heavy metals are fairly immobile in the soil and do not undergo biodegradation or transformation processes. Although some organic COECs can undergo biodegradation or transformations, these processes tend to be fairly slow for the types of COECs at EBG (e.g., pesticides, PAHs, and PCBs). Ecological succession could result in a change of specific vegetation composition, but the relatively small size of the terrestrial EUs at EBG should minimize changes in the types of ecological receptors. Thus, because the future concentrations of COECs, as well as the future types of ecological receptors, are not expected to change dramatically from the current conditions, future risk is expected to be similar to the current risk indicated by the HQs.

The current HQs for the terrestrial plants and animals at the EBG EUs are assumed to be the same or similar to future HQs because most of the soil COPEC concentrations are not expected to change dramatically over time, assuming there are no disturbances to the soil. For example, most inorganic COECs like the heavy metals are fairly immobile in the soil and do not undergo biodegradation or transformation processes. Although some organic COECs can undergo biodegradation or transformations, these processes tend to be fairly slow for the types of COECs at EBG (e.g., pesticides, PAHs, and PCBs). Ecological succession could result in a change of specific vegetation composition, but the relatively small size of the terrestrial EU at EBG should minimize changes in the types of ecological receptors. Thus, because the future concentrations of COECs, as well as the future types of ecological receptors, are not expected to change dramatically from the current conditions, future HQs are expected to be similar to the current HQs.

In the aquatic habitats, future HQs are likely to remain the same as those associated with current conditions. Nothing is expected to change in terms of newly introduced contaminants through erosion or overland surface water movement to the ponds and wetlands. Such transfers have occurred many years ago in the case of organics and likely inorganics too. The aspect, soil type, and vegetation cover on the land greatly reduces any potential movement of soil-bound contaminants. Given that the wetlands at EBG were determined to be high quality according to the Ohio rapid assessment method and that biological communities were determined to be functioning according to the facility-wide biology and surface water study, these ecological resources are expected to remain of similar quality and functioning.

7.10.6 Summary of Hazard Quotient Calculations

EU-specific preliminary COPECs for surface soil, subsurface soil, sediment, and surface water from the Level II ESV screen were inputted to this Level III BERA where they underwent EU- and receptor-specific HQ calculations. Following the HQ calculations, the COPECs were classified into one of three categories: (1) NFA, (2) COECs per HQs > 1, or (3) COECs per “no TRV.”

7.11 UNCERTAINTIES FOR THE BASELINE ECOLOGICAL RISK ASSESSMENT

Uncertainties in the EBG BERA are discussed briefly in this section by the four interrelated steps of the EPA approach to a BERA: problem formulation, exposure assessment, effects assessment, and risk characterization. An uncertainty section of a more general and SERA-specific nature is found in Section 7.5.

7.11.1 Uncertainties in Problem Formulation

Environmental concentrations of analytes in the soil, sediment, and surface water at EBG were based on a limited number of samples. A degree of uncertainty exists about the actual spatial distribution of constituents. Exposure concentrations could be overestimated or underestimated, depending on how the actual data distribution differs from the measured data distribution. Because the estimated UCL_{95} of the mean concentrations or MDC was used as the EPC concentration to calculate HQs, the estimates of risk from COPECs are conservative (i.e., protective). Using UCL_{95} or maximum concentrations decreases the likelihood of underestimating the risk posed by each COPEC and increases the likelihood of overestimating the risk.

The full distribution and abundance of organisms comprising the ecological receptors at EBG has not been quantified by field studies. The lack of quantitative data introduces uncertainties concerning whether, and to what extent, the risk characterization based on the selected receptor species underestimates or overestimates the risk to organisms that were not used in the risk computations but that occur at EBG. On-site reconnaissance has established the nature and quality of habitat and has confirmed the presence of vegetation types and of active, visible animal species. Observations made during this reconnaissance justify assumptions about the presence of unobserved organisms that are essential to normal ecosystem functioning, such as soil-dwelling worms and arthropods and herbivorous insects. This area falls within the acceptable range of each species. Note that the extrapolations of no ecological effects at WBG (SAIC 2002) may moderate this type of uncertainty and show HQs at EBG to be an overestimate of risk. However, as explained in Section 7.1, there are many differences (much water, site histories, soil, and so forth) that preclude outright extrapolation from WBG to EBG.

It is possible that one (or more) unobserved species at EBG is more sensitive than the ecological receptors for which toxicity data are available for use in the ERA. It does not necessarily follow that these unevaluated, more sensitive species are at significantly greater risk than the species estimated in this ERA because exposure concentrations for ecological receptors in this ERA could be greater than those for more sensitive receptors due to different dietary regimes.

7.11.2 Uncertainties in Exposure Assessment

The actual movement of analytes from the EBG constituent source media to ecological receptors has not been measured for this BERA. This introduces uncertainties about the actual modes and pathways of exposure, bioavailability of constituents, and the actual exposure concentrations of these analytes to the ecological receptors. Actual exposure concentrations can differ from the measured environmental concentrations as a result of physical and chemical processes during transport from source to receptor and as a result of biomagnification through the food web. Actual exposure concentrations in physical media are sometimes less than the total measured concentrations because a portion of the total constituent is not bioavailable to the receptors. These processes have not been evaluated quantitatively in this SERA. Thus, the exposures could be overestimated based on the total measured concentration.

BAFs for soil and sediment to biota, and BAFs for surface water to biota, used for the PBT evaluation, are not available for some analytes. Instead, default values were used. It is not known whether this substitution overestimates or underestimates exposure. However, the default values are thought to be conservative, so it is likely that exposures will not be underestimated.

Literature-derived factors to describe dietary intake and bioaccumulation of elements may not reflect actual diets and bioaccumulation at the site. However, the literature values are assumed to be sufficiently similar to site-specific values that exposures neither will be underestimated nor overestimated.

Exposure concentrations are likely to be overestimated because of conservative exposure factors. Exposure factors include published BAFs, irrespective of species and environmental conditions. In particular, it should be noted that, while the largest BAFs may overestimate bioaccumulation at EBG by at least one order of magnitude for some COPECs, very high bioaccumulation, as well as biomagnification, are well-documented for other constituents, although not necessarily all those likely detected.

Finally, the exposure of plants and animals to constituents below detection limits was not considered in the BERA. In addition, the exposure of ecological receptors to tentatively identified compounds is not considered, which could result in an underestimation of exposure.

7.11.3 Uncertainties in Effects Assessment

The preferred TRVs for the three media were based on concentrations reported to have no observed effects or NOAELs for various organisms. This BERA provides findings for COPEC-specific HQs. An evaluation of risk from COPEC mixtures cannot be conducted without additional data and evaluation of alternative models of COPEC interaction.

There are no available TRVs for some analytes, especially organics, for each of the three media. This contributes to uncertainty associated with likely underestimates of risk. Sometimes, lack of TRVs based on soil-plant studies caused use of TRVs based on hydroponic studies; hydroponic studies are inferior to soil-plant studies and this contributed additional uncertainty.

7.11.4 Uncertainties in Risk Characterization

The uncertainties described above ultimately produce uncertainty in the quantification of current and future risks to terrestrial and aquatic animals at EBG. Five additional areas of uncertainty in the risk characterization exist: off-site risk, cumulative risk, future risk, background risk, and extrapolation risk.

7.11.5 Extrapolation Risk

Yet another source of uncertainty revolves around the extrapolations of WBG plant protection levels to EBG. No one AOC and no one EU is exactly like the others. Differences in concentrations and chemical mixtures introduce variation into extrapolations.

7.11.6 Summary of Uncertainties

The most important uncertainties in the EBG BERA are those surrounding the estimates of the constituent concentrations to which ecological receptors are actually exposed (exposure concentrations) and the concentrations that present an acceptable level of risk of harmful effects (TRVs). These uncertainties arise from multiple sources, but especially from the lack of site-specific data on constituent transport and transformation processes, bioavailability of contaminants, organism toxicity, and the response of plant and animal populations to stressors in their environments. Despite these uncertainties, the available site-concentration data and published exposure and effects information are believed to provide a sufficiently credible picture of ecological risk that management decisions can be made with confidence.

7.12 SUMMARY OF ERIE BURNING GROUNDS LEVEL II AND III BASELINE RISK ASSESSMENT

The EBG site contains sufficient terrestrial and aquatic (soil, sediment, and surface water) habitat to support various classes of ecological receptors. For example, terrestrial habitats at EBG include woodlots, marshy areas, and open water. Various classes of receptors, such as vegetation, small and large mammals, and birds, have been observed at the site. In addition, an Ohio Rapid Wetland Assessment was performed at the AOC, and this showed the wetlands to be of high quality. 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 and Level III BERA were performed for EBG soils (surface and subsurface), sediment, and surface water using Ohio EPA and Army guidance methods. The Level II Screen consisted of a media-specific data evaluation and media evaluation of detected COIs, as well as a media screen. The data and media evaluations 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 and media evaluations were carried forward to the media screen. The media screen entailed comparing concentrations of inputted chemicals against ESVs (for soil and sediment) and OAC WQC for surface water. Chemicals whose concentrations exceeded or lacked the ESVs or OAC WQC, as well as chemicals that were PBT compounds, were retained as COPECs while all other chemicals were eliminated from further action.

7.12.1 Level II Results

For surface soil (0 to 1-ft depth), 53 detected COIs were inputted into the data and media evaluations, wherein 5 were eliminated due to low frequency of detection and not being PBT compounds, so 48 were identified as COPECs and carried forward to the media screening. Of the 48 COPECs inputted into the media screening, 8 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 40 chemicals were retained as COPECs for surface soil.

For subsurface soil (1 to 3 ft), 43 detected COIs were inputted into the data and media evaluations, wherein 19 were eliminated due to either low frequency of detection or MDC being less than background and not being PBT compounds, so 24 were identified as COPECs and carried forward to the media screening. Of the 24 COPECs inputted into the media screening, six were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 18 chemicals were retained as COPECs for subsurface soil.

For sediment, 58 detected COIs were inputted into the data and media evaluations, wherein 12 were eliminated due to either low frequency of detection or MDCs being less than the Ohio EPA SRVs or background and they were not PBT compounds. Thus, 46 of the 58 detected COIs were identified as COPECs and carried forward to the media screening. Of the 46 COPECs inputted into the media screening, only 2 were eliminated because their concentrations did not exceed their ESVs and they were not PBT compounds, so 44 chemicals were retained as COPECs for sediment.

For surface water, 39 detected COIs were inputted into the data and media evaluations, wherein 7 were eliminated due to MDCs being less than background and not being a PBT compound. Thus, 32 of the 39 detected COIs were identified as COPECs and carried forward to the media screening. Of the 32 COPECs inputted into the media screening, 15 were eliminated because their concentrations did not exceed their OAC WQC and they were not PBT compounds, so 17 chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for surface and subsurface 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 were used to prepare a Level III BERA.

Thus, 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 EBG site, a SMDP was made to conduct a Level III BERA to identify COECs and constituents that qualify for NFA.

7.12.2 Level III Results

Multiple COECs for surface soil were identified for the EU at EBG (Table 7-8). The EU-specific soil COECs were identified by having met one of two conditions: (1) the preliminary COPEC RME concentration yielded an HQ > 1 for at least one ecological receptor exposed to the surface soil, or (2) the EBG preliminary COPEC had no TRV for one or more receptors. Eleven COECs were identified based on at least one HQ > 1, along with 32 COECs based on no TRV for at least one receptor. Six of the 32 COECs based on no TRV also had at least one receptor with an HQ > 1. There were three inputted surface soil COPECs from the Level II SERA that were identified as qualifying for NFA during the Level III BERA.

Multiple COECs for subsurface soil were identified for the EU at EBG (Table 7-8). Two COECs (antimony and zinc) were identified based on at least one HQ > 1, along with 13 COECs based on no TRV for at least one receptor. One of the 13 COECs based on no TRV also had at least one receptor with an HQ > 1. There were four inputted surface soil COPECs from the Level II SERA that were identified as qualifying for NFA during the Level III BERA.

Multiple COECs for sediment were identified at the EU at EBG (Table 7-8). Twenty-three COECs were identified based on at least one HQ > 1, along with 35 COECs based on no TRV for at least one receptor. Five of the COECs based on no TRV also had at least one receptor with an HQ > 1. There was only one inputted surface soil COPEC from the Level II SERA that qualified for NFA during the Level III BERA.

Multiple COECs were identified for surface water at the surface water EU (Table 7-8). Ten COECs were identified based on at least one HQ > 1, along with nine COECs based on no TRV for at least one receptor. Two of the COECs based on no TRV also had at least one receptor with an HQ > 1. None of the inputted surface water COPECs from the Level II SERA qualified for NFA during the Level III BERA because they all either had at least one HQ >1 or no TRV.

7.12.3 Recommendation

There is sufficient information from the Level II and III risk assessments, Ohio rapid wetland assessment, and Facility-wide Biological and Water Quality Study 2003, all at EBG, to clarify that there are valuable wetland/aquatic ecological resources that are experiencing some ecological risk. There is no need for more studies, rather a strategy of how to best use that information. That strategy, in terms of likely outcomes, is explained next.

The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in the assessment endpoint table, are listed below.

1. Risk management of the ecological resources, although they are limited and include a high quality wetland as shown, by applying the Ohio rapid wetland habitat assessment at EBG.

2. Remediation of some of the source material if land use (assumed to be restricted access because of MEC and wetland quality) and other evidence, such as site-related usage COPECs, really warrant it.

3. Conduct of more investigation, such as a Level IV Field Baseline, 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 EBG.

Note that other logical outcomes, mentioned in Table 7-7, 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 EBG would assist in defining the best outcome or decision. The WOE would use such topics and proposed purposes as follows:

(a) Useful findings of the ecological screening level work (Level II and Level III) — those chemicals, whose HQs exceed the regulatory trigger of 1,

(b) EBG-specific biological and water quality fieldwork (from the study by the same names at RVAAP) — little to no appearance of impact to the biological community,

(c) High quality wetland habitat assessment at EBG (from the Ohio rapid wetland assessment) — constitutes a valuable, functioning environmental resource,

(d) Military land use — influences the land management practices and their priorities,

(e) Degree of correlation of site usage or suspected usage COPECs (from step 4 of the RVAPP facility-wide ecological work plan) — may delimit COPECs,

(f) Possibility of remediation — letting status quo habitat remain likely has less negative impact than source removal, and

(g) Other, including the need or lack of need for ecological RAOs. The WOE will be part of the FS.

7.12.4 Final Summary

The screens in Level II and the HQ work in Level III systematically removed chemicals from further consideration. However, some chemicals remain as COECs at the conclusion of the ERA. For example, surface soil started with 53 detected COIs and ended with 11 COECs with HQs > 1; most of these are inorganics. Subsurface soil started with 43 detected COIs and ended with 2 COECs with HQs > 1; these are antimony and zinc. For sediment, the process started with 58 detected COIs and ended with 23 COECs with HQs > 1; these are a mixture of inorganics and organics. Surface water had 39 detected COIs and ended with 10 COECs with HQs > 1; these are all inorganics. The conclusion of the ERA and listing of final COECs are available to the RVAAP Team to allow a more informed scientific management decision on the path forward for EBG as discussed in Chapters 8.0 and 9.0.

The most likely outcomes, in order of likelihood, associated with the SMDP for the ERA, as mentioned in Table 7-7 and Section 7.12.3, 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 EBG would assist in defining the best outcome or decision. Thus, the information in this Level III ERA can be used to assist managers in making their decision associated with the SMDP.

8.0 SUMMARY AND CONCLUSIONS

The EBG Phase II RI Report presents a detailed analysis of the environmental data collected during the Phase II RI field effort. This summary incorporates these data, along with Phase I RI results, into an overall description of the characterization of the AOC. 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 II RI information with previous Phase I data, is presented to integrate results of all site assessments 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., surface water basins and groundwater), and exit pathways from the AOC. The conclusions 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 II RI evaluated the nature and extent of contamination in both discrete and multi-increment surface soil (0 to 1 ft bgs), discrete and multi-increment sediment samples (0 to 0.5 ft bgs), surface water, and groundwater. Subsurface soil characterization was done only in context of geotechnical characteristics. Multi-increment samples and groundwater samples were collected only during the Phase II RI, and subsurface samples for chemical analyses were done only during the Phase I RI. All other media were sampled in both phases of investigation.

8.1.1.1 Data aggregates/exposure units and data reduction

All media 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 discrete 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 EBG. All discrete samples were analyzed for explosives, TAL metals, cyanide, and SVOCs; three discrete samples were analyzed for propellants; two discrete samples were analyzed for VOCs and pesticides/PCBs. In addition, multi-increment samples were collected from five approximately equal areas within the AOC, exclusive of the surface water basins. 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 in Phase I and II RI samples collected along the Track 49 embankment, the gravel access road, at isolated locations on the north and east legs of the T-Area, the Former Borrow Area, and the Former Burn Area. No explosives were found in the wooded area south of the T-Area or on the west leg of the T-Area. Inorganics are pervasive in surface soil at EBG. Aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc were detected in many or all of the surface soil samples. At least 30% of these detections are at concentrations above the facility-wide background. The highest concentrations of inorganics in surface soil are associated with the Former Burn Area, the Track 49 embankment, and the T-Area. SVOC contamination of surface soils is primarily bis(2-ethylhexyl)phthalate and PAHs; these occur primarily along the Track 49 embankment, the gravel access road, and the north leg of the T-Area. VOCs were only sporadically detected in surface soils. PCB compounds were not detected in any of the Phase I or Phase II RI surface soil samples. The extent of explosives contamination to detection limits has not been delineated; however, the Phase I and II RIs have identified and delineated the areas containing the highest levels of this class of compounds.

Surface Soil Multi-increment Samples

Multi-increment soil samples were collected from five separate areas at EBG. Explosives were detected at one multi-increment sample location from the Track 49 embankment area. Inorganic constituents were detected at all multi-increment sample locations. The number of constituents that exceeded background concentrations ranged from 2 to 14, with antimony, cadmium, chromium, copper, mercury, silver, and zinc being the most frequently observed above background. At least one SVOC was detected in four of the five multi-increment samples. As many as 12 SVOCs were detected in the multi-increment samples. The greatest number of compounds was reported for the multi-increment sample from the Track 49 embankment.

8.1.1.3 Subsurface soil

Subsurface soil samples (1 to 3 ft bgs) were collected only during the Phase I RI. Most detected compounds occurred mainly along Track 49, the gravel access road, and the T-Area. In general, concentrations and occurrence were lower in subsurface soil than in surface soil. The most frequently detected explosive was 2,4,6-TNT, with sporadic detections of other explosives and one propellant. Inorganics are pervasive in subsurface soil at EBG. Aluminum, arsenic, barium, chromium, cobalt, copper, lead, manganese, nickel, vanadium, and zinc were detected in 100% of the subsurface soil samples. The SVOC bis(2-ethylhexyl)phthalate and PAH compounds were detected in subsurface soil As was the case for surface soil samples, VOCs were only sporadically detected in subsurface soils and no PCB compounds were detected.

8.1.1.4 Sediment

Seven discrete sediment samples and samples from two sediment multi-increment sampling areas were collected during the Phase II RI. All sediment samples were analyzed for explosives and propellants, metals, SVOCs, VOCs, and pesticides/PCBs.

Discrete Sediment Samples

Explosives in sediments are limited in occurrence and have only been detected in the Track 49 embankment area and at the north inlet, in the former drainage channel in the south basin, and at the EBG outlet. No explosives occurred at off-site sediment sample stations, suggesting these compounds are not migrating off the AOC. Metal SRCs in sediments in the T-Area primarily exist along the north leg closest to Track 49. The Former Burn Area contains comparatively high numbers and concentrations of SRCs. Other notable areas of metal SRC occurrence include the north and east inlets and the former drainage channel in the southern basin. SVOCs were distributed one of two ways: (1) stations exhibiting PAH contamination and (2) stations exhibiting bis(2-ethylhexyl)phthalate and/or 4-methylphenol. The occurrence of samples containing predominantly phthalates or phenols was primarily within the access road, the staging/parking area, and the surface water basins. The maximum concentration of bis(2-ethylhexyl)phthalate was observed in the Former Burn Area. The occurrence of PAH compounds was primarily within the Track 49 area, the access road, and the Former Burn Area. Acetone, 2-butanone, and toluene were the most frequently detected VOCs in sediments at EBG, with other VOCs detected in one sample each. No pattern was noted for the distribution or concentrations of acetone or 2-butanone. Most of the detectable toluene concentrations occurred in the Track 49 vicinity and the Former Burn Area. PCB-1254 was detected in one sediment sample collected within the Former Burn Area during the Phase I RI. The pesticide methoxychlor was detected in one sediment sample within the former drainage channel during the Phase II RI.

Sediment samples from the north and east surface water basins exhibited the majority of metal SRCs above background. Overall, the south surface water basin and west leg of the T-Area contain few SRCs. Some metals, SVOCs and VOCs were detected at low concentrations relative to detection limits or background values at the surface water exit point at the southwest corner of EBG.

Multi-increment Sediment Samples

Three multi-increment samples were collected from each of two multi-increment sampling areas, one located in the north basin, and one in the south basin along the axis of the former drainage channel. The north basin multi-increment samples displayed generally better reproducibility of results than the south basin samples. With the exception of pesticides, all three samples from the north basin had similar constituents and concentrations. Notably, only one of the three south basin samples had detections of explosives. Overall, explosives, metals, SVOCs, and pesticides were all more prevalent in the north basin multi-increment samples than in the south basin multi-increment samples.

8.1.1.5 Surface water

Explosive compounds were not detected at the eight surface water stations sampled during the Phase II RI. The propellant nitrocellulose was detected in the Phase II surface water sample collected from the east inlet. The absence of explosives in Phase II surface water samples contrasts with the results of the Phase I samples, which showed explosives in surface water in the vicinity of the T-Area and the east inlet, and outside the AOC at the EBG outlet and at PF534. Based on Phase II RI results, migration of dissolved-phase explosives off of the AOC in surface water appears to be minimal.

No new inorganic SRCs were identified as a result of Phase II RI sampling, and the assessment of the distribution and occurrence of inorganic SRCs did not change substantially. In the Phase I RI, inorganics above background occurred primarily within the T-Area and the east surface water basin. The tributary draining EBG contained multiple metals above their background at the confluence with a drainage ditch exiting the ore pile storage area. The north, west, and south surface water basins, and the EBG outlet contained a limited number of metal SRCs. Three sample points located off-site of EBG also contained metals above background values. In the Phase II RI, the greatest number of inorganics above background occurred in the surface water sample collected from the former drainage channel in the south basin; few SRCs were observed in this area in the Phase I RI. Inorganics were also detected above background at the EBG outlet (EBG-157) and stations immediately downstream (EBG-158 and -159), as well as the off-AOC location (EBG-161) at PF534.

Low concentrations of two SVOCs were detected in EBG surface water samples collected during the Phase I RI; however, SVOCs were not detected in the Phase II RI surface water samples. Low concentrations of VOC compounds were detected in both Phase I and Phase II RI surface water samples. VOCs most frequently detected in surface water during the Phase I RI (i.e., acetone, toluene, and carbon disulfide) were not detected in Phase II RI samples. The majority of detected VOCs in Phase II RI surface water samples occurred in the T-Area with detections also at the east inlet. It is unclear whether these low levels of VOCs detected in Phase II RI samples collected within the T-Area and at the east inlet are related to former AOC operations. Pesticides and PCB compounds were not detected in surface water samples collected during the EBG Phase I or Phase II RIs.

8.1.1.6 Groundwater

Eight new groundwater wells were installed and sampled during the Phase II investigation. Explosives were not detected in any of the groundwater samples collected during the Phase II RI. The absence of explosives in groundwater during the Phase II RI indicates that leaching of explosives contamination present in soils and sediment to the groundwater table is minimal or that dilution factors are very high.

Nine inorganics were identified as groundwater SRCs (antimony, arsenic, barium, cobalt, copper, lead, nickel, vanadium, and zinc). Of these, arsenic, barium, and nickel were detected at all eight monitoring wells. Inorganics were detected above background criteria as often in wells located at the AOC boundary as in wells located in the center of known surface soil and sediment contamination. Maximum concentrations ranged from only 2 to 3 times background when background criteria were above zero.

Few SVOCs, VOCs, and pesticides were detected in groundwater samples. Bis(2-ethylhexyl)phthalate and di-n-butyl phthalate were detected in one and two wells, respectively, in the area of the Track 49 embankment/northern T-Area. Carbon disulfide was the only VOC detected in groundwater. The pesticide 4,4’-dichlorodiphenyltrichloroethene was detected in groundwater at the southwestern corner of EBG. PCBs were not detected in groundwater samples.

8.1.2 Contaminant Fate and Transport

Contaminant fate and transport modeling performed as part of the Phase II RI included leachate modeling using SESOIL and groundwater transport modeling using AT123D. The source area selected for the modeling effort was the Track 49 Embankment. The receptor point selected for leaching was the groundwater table immediately below the source. The receptor for groundwater transport modeling was the south surface water basin. Because the south basin is immediately adjacent to the Track 49 embankment, the transport distance to the receptor is minimal; thus, the AT123D model was used to predict the concentration in groundwater after dilution due to hydrodynamic dispersion and mixing.

RDX and arsenic were identified as final CMCOPCs for EBG based on source loading predicted by the SESOIL modeling. These two constituents were also identified as final CMCOCs based on AT123D modeling. The maximum leachate concentrations of these constituents at the groundwater table were predicted to exceed MCLs or RBCs at the water table within the model time frame of 1,000 years. The predicted peak leachate concentration for RDX was modeled to occur within only 4 years. Considering that EBG operations ceased approximately 50 years ago, predicted peak concentrations have likely passed. The absence of RDX in samples collected from groundwater monitoring wells installed within the source area indicate that factors such as attenuation and adsorption mitigate the leaching and migration of contaminants to a greater degree than assumed in the numerical model.

8.1.3 Human Health Risk Evaluation

The HHRA was conducted to evaluate risks and hazards associated with contaminated media at EBG at RVAAP. Risks and hazards were estimated for two representative receptors (Hunter/Trapper and Fire/Dust Suppression Worker) exposed to three media (shallow surface soil, from a depth interval of 0 to 1 ft bgs, sediment, and surface water). Risks and hazards were also estimated for potential exposure to surface soil, subsurface soil, groundwater, sediment, and surface water by three additional receptors [National Guard Trainee, Security Guard/Maintenance Worker, and Resident Subsistence Farmer (adult and child)].

The following steps were used to generate conclusions regarding human health risk and hazards associated with contaminated media at EBG:

- identification of COPCs,
- calculation of risks and hazards,
- identification of COCs, and
- calculation of RGOs.

No surface soil or sediment COCs were identified for either representative receptor (Hunter/Trapper and Fire/Dust Suppression Worker) at EBG. One metal (arsenic) was identified as a carcinogenic COC for the Fire/Dust Suppression Worker exposed to surface water at EBG. The representative receptors are not exposed to groundwater.

For future risk management decisions, a risk-based RGO was computed for the identified COC (arsenic) in surface water at a TR of 10^{-5} and a THI of 1. Comparison of the RGO to the EPC for arsenic in EBG surface water indicated that the EPC was less than the most conservative risk-based RGO.

Wildfowl concentrations were modeled for all COPCs identified in the sediment and surface water at EBG. Subsequent calculations of risks and hazards resulted in the determination of four COCs for the Hunter/Trapper exposed via the ingestion of wildfowl pathway. Antimony and zinc were identified as non-carcinogenic COCs. Arsenic and benzo(*b*)fluoranthene were identified as carcinogenic COCs. Because the ingestion of wildfowl is not a direct contact pathway, risk-based RGOs were not computed for the four COCs.

While a land use plan has been drafted for the RTLS, 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). To address this uncertainty, additional receptors (e.g., National Guard Trainee) 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.

COCs identified for direct contact pathways for all media for the other receptors evaluated are listed below.

- Two COCs [arsenic and benzo(*a*)pyrene] were identified in shallow (0 to 1 ft bgs) surface soil.

- Three COCs (arsenic, chromium, and manganese) were identified in deep (0 to 3 ft bgs) surface soil.

- Two COCs [arsenic and benzo(*a*)pyrene] were identified in subsurface soil.

- One COC (arsenic) was identified in groundwater.

- Five COCs [antimony, arsenic, chromium, manganese, and benzo(*b*)fluoranthene] were identified in sediment.

- Two COCs (arsenic and manganese) were identified in surface water.

RGOs were calculated for all COCs identified for all receptors.

8.1.4 Ecological Risk Evaluation

The EBG site contains sufficient terrestrial and aquatic (e.g., 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 SERA. Thus, Ohio EPA protocol (Level I) was met and Level II was needed.

A Level II SERA and Level III BERA were performed for EBG soils (surface and subsurface), sediment, and surface water using Ohio EPA and Army guidance methods. The Level II Screen consisted of a media-specific data evaluation and media evaluation of detected COIs, as well as a media screen. Chemicals whose concentrations exceeded or lacked the ecological screening values or OAC water quality standards, as well as chemicals that were PBT compounds, were retained as COPECs.

Level II Results

Forty-five chemicals were retained as COPECs for surface soil. For subsurface soil (1 to 3 ft depth), 18 chemicals were retained as COPECs. Forty chemicals were retained as COPECs for sediment. Seventeen chemicals were retained as COPECs for surface water.

Because COPECs were identified and retained for surface and subsurface 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 were used to prepare a Level III Baseline.

Level III Results

The results of the Level III screening are summarized in Table 7-8. Forty-three COECs for surface soil were identified for the EU at EBG; three of the surface soil COPECs from the Level II SERA were identified as qualifying for NFA during the Level III BERA. Fifteen COECs for subsurface soil were identified for the EU at EBG. Four subsurface soil COPECs from the Level II SERA were identified as qualifying for NFA during the Level III BERA. Fifty-eight COECs for sediment were identified at the EU at EBG; however, only one surface soil COPEC from the Level II SERA qualified for NFA during the Level III BERA. Nineteen COECs were identified for surface water at the surface water EU. None of the surface water COPECs from the Level II SERA qualified for NFA during the Level III BERA. 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 EBG would assist in defining the best outcome or decision. Thus, the information in this Level III ERA can be used to assist managers in making their decision associated with the SMDP.

8.2 CONCEPTUAL SITE MODEL

The preliminary EBG CSM, developed as part of the Phase I RI (USACE 2001c), was summarized in Chapter 2.0. A revised CSM is presented in this section that incorporates Phase II 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

The results of Phase I and II RI soil sampling identified the Track 49 embankment, the gravel access road, and the north leg of the T-Area as the portions of EBG with the greatest numbers and concentrations of contaminants. No original waste residues were observed at the site; however, metals, explosives, and SVOCs are present in soils in these areas at concentrations greater than background or risk screening criteria. The majority of contamination is restricted to the surface soil interval less than a depth of 0.9 m (1.0 ft). In particular, the north side of the Track 49 embankment west of the Former Burn Area contained the highest levels of contaminants within the AOC. Therefore, surface soils in these three areas are considered to be residual or secondary sources of contamination at EBG. The rail spur itself is a suspected source for PAHs and inorganics observed in soil. Slag in the rail bed and creosote-coated rail ties are still present on Track 49 and may contribute to observed soil contamination.

The east leg of the T-Area also exhibited contamination, but to a lesser degree than the three subareas noted above. The Former Borrow Area, the northwestern and south wooded areas, and the west leg of the T-Area do not appear to be significant source areas.

Contaminated sediments in the Former Burn Area and north side of the Track 49 embankment, as well as the north leg of the T-Area and north end of the gravel access road, are secondary sources of contaminants when soluble contaminants dissolve in surface water. Sediment may also be a transport mechanism when contaminated sediment is mobilized in surface water flow under storm conditions.

The primary mechanisms for releases of contaminants from the source areas listed above include the following:

- past thermal destruction of waste munitions, explosives, and associated wastes;
- leaching of constituents from the residual ash and debris into soils;
- erosion of contaminated soils and redeposition in surface water bodies; and
- soil and sediment leaching to groundwater.

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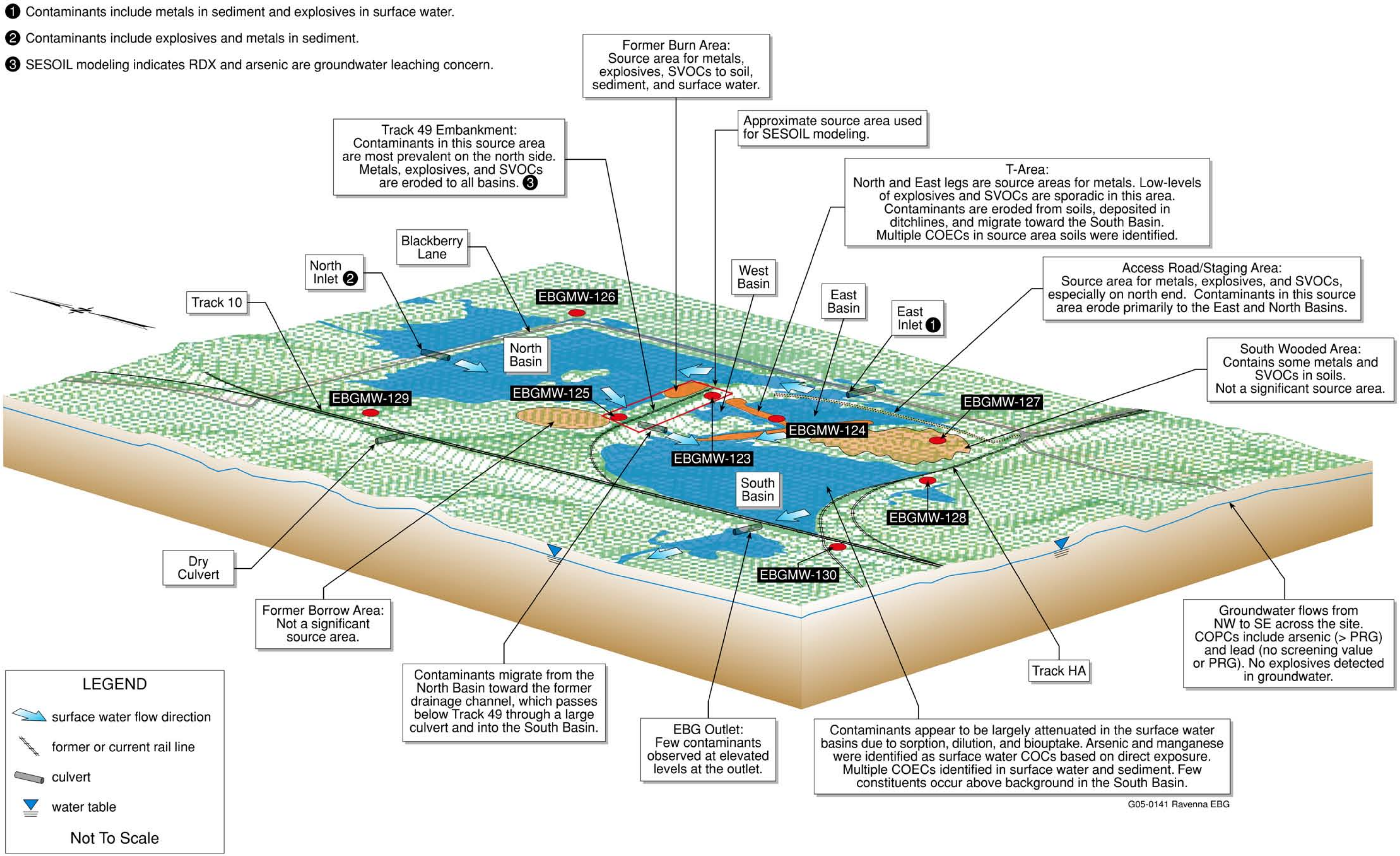

❶ Contaminants include metals in sediment and explosives in surface water.

❷ Contaminants include explosives and metals in sediment.

❸ SESOIL modeling indicates RDX and arsenic are groundwater leaching concern.

Former Burn Area: Source area for metals, explosives, SVOCs to soil, sediment, and surface water.

Track 49 Embankment: Contaminants in this source area are most prevalent on the north side. Metals, explosives, and SVOCs are eroded to all basins. ❸

Approximate source area used for SESOIL modeling.

T-Area: North and East legs are source areas for metals. Low-levels of explosives and SVOCs are sporadic in this area. Contaminants are eroded from soils, deposited in ditchlines, and migrate toward the South Basin. Multiple COECs in source area soils were identified.

Access Road/Staging Area: Source area for metals, explosives, and SVOCs, especially on north end. Contaminants in this source area erode primarily to the East and North Basins.

South Wooded Area: Contains some metals and SVOCs in soils. Not a significant source area.

Former Borrow Area: Not a significant source area.

Contaminants migrate from the North Basin toward the former drainage channel, which passes below Track 49 through a large culvert and into the South Basin.

EBG Outlet: Few contaminants observed at elevated levels at the outlet.

Contaminants appear to be largely attenuated in the surface water basins due to sorption, dilution, and biouptake. Arsenic and manganese were identified as surface water COCs based on direct exposure. Multiple COECs identified in surface water and sediment. Few constituents occur above background in the South Basin.

Groundwater flows from NW to SE across the site. COPCs include arsenic (> PRG) and lead (no screening value or PRG). No explosives detected in groundwater.

Figure 8-1. Site Conceptual Model for Erie Burning Grounds

Metals and organic residues are present in the groundwater below EBG. Metal SRCs identified in the groundwater are antimony, arsenic, barium, cobalt, copper, lead, nickel, vanadium, and zinc. Organic SRCs identified include phthalates, and sporadic occurrences of pesticides and VOCs.

8.2.2 Groundwater Flow and Contaminant Migration Pathways and Exit Points

Groundwater Pathways

Groundwater at EBG generally flows from northwest to southeast, through silt/sand layers within the glacial outwash and recent alluvium. Soil of the Sebring series silt loams is dominant. In particular, silty clays and silty sands dominate. Contaminant leaching pathways from soil to the water table are through the soil cover. The vadose zone in the Track 49 embankment area consists of fill/soil up to approximately 7 ft thick at the crest of the embankment. Within the T-Area, the unsaturated zone thickness ranges from several feet to less than 1 ft.

SESOIL modeling results indicate that RDX and arsenic may leach from the source area soil (e.g., the Track 49 embankment) to groundwater beneath the AOC. However, monitoring data do not currently support this prediction. No explosives were detected in any of the eight groundwater wells installed during the Phase II RI. Arsenic, along with many other metal SRCs, was detected in groundwater above risk-based screening criteria, but these metals are pervasive throughout RVAAP soils, sediment, surface water, and groundwater. Site hydrogeologic conditions indicate a high degree of groundwater-surface water interaction throughout EBG, which favors high dilution factors within the uppermost groundwater zones. Thus, groundwater transport does not appear to be a major mechanism for contaminant transport off of the AOC.

Surface Water Pathways

Migration of contaminants from soil sources to surface water conveyances occurs primarily by: (1) movement of particle-bound contaminants in surface water runoff, and (2) transport of dissolved constituents in surface water. Upon reaching surface water conveyances, in particular the surface water basins, flow velocities decrease and particle-bound contaminants largely settle out as sediment accumulation. Sediment-bound contaminants may migrate if they are mobilized during storm events or in dissolved phase in surface water.

The principal contaminant exit pathway from EBG is surface water flow to the southeast via the culvert beneath Track 10. Dissolved-phase contaminants in surface water and remobilized sediment, particularly along the T-Area ditch lines and surface water basin north of Track 49, migrate slowly toward the exit point under ambient gradients. This migration pattern was evident in the observed distribution of sediment contamination, which suggested migration from the northern embankment of Track 49 toward the former drainage channel bisecting EBG. However, the great amount of vegetation, beaver activity, and flat topography at the site greatly reduces surface water flow rates within EBG and maximizes the potential for settling, sorption onto organic matter, and biological uptake. Substantial dilution is postulated to occur within the surface water basins given their large volumes. The low numbers and concentrations of SRCs in sediment samples from stations immediately downstream of the outlet culvert suggest these processes are effective at attenuating constituents and restricting their migration from EBG. Storm events may produce flushing of the surface water system and result in periodic transport beyond the site boundary. The culvert beneath Track 10 in the northwest portion of the AOC is primarily dry and water levels would have to be very high within EBG for flow to occur through this outlet.

The presence of explosives at the RVAAP exit point (PF534) detected during Phase I could not be conclusively attributed to EBG and were not repeated during the Phase II RI. Results of analyses of

Phase I samples located midpoint between PF534 and EBG and results of Phase II samples a short distance downstream of the EBG outlet did not indicate any explosives in surface water.

8.2.3 Uncertainties

The CSM is developed based on available site characterization and chemical data. Uncertainties are inherent in the CSM depending on density and availability of data. The CSM for EBG is well defined using Phase I and II RI data and major data gaps do not remain to be resolved. However, some uncertainties for the CSM for EBG include the following:

- Characterization of surface water was performed under dry conditions and at normal pool conditions in the Phase I and Phase II RIs, respectively. These data do not suggest high contaminant fluxes exiting EBG at principal drainage culverts. However, contaminant transport related to high flows during storm events (flushing effects) has not been characterized.

- The AOC groundwater monitoring network indicates that the extent of groundwater contamination associated with the AOC has been defined. However, it is recognized that groundwater flow may occur through preferential pathways within the glacial outwash deposits underlying EBG and that the monitoring wells may 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, subsurface soil, groundwater, sediment, and surface water at EBG at an HI of 1 or risk level of 10^{-5}.

8.3.1 Surface Soil

Explosives, metals, SVOCs, and VOCs were detected above background in surface soil samples at EBG. Fate and transport modeling indicates that RDX and arsenic may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs. Explosive compounds and inorganics above background levels were detected in the westernmost samples collected along the Track 49 embankment.

No surface soil human health COCs were identified for any exposure scenario or pathway for either of the representative receptors at EBG (Hunter/Trapper or Fire/Dust Suppression Worker). Two COCs [arsenic and benzo(*a*)pyrene] were identified in shallow (0 to 1 ft bgs) surface soil and three COCs (arsenic, chromium, and manganese) were identified in deep (0 to 3 ft bgs) surface soil for the other receptors evaluated.

The Level III BERA identified 43 COECs for surface soil at EBG.

8.3.2 Subsurface Soil

The Phase I RI indicated that explosives, metals, SVOCs, and VOCs occur in subsurface soil at concentrations exceeding background. Fate and transport modeling indicates that RDX and arsenic may leach from soil and sediment to groundwater beneath the source at levels above MCLs or RBCs.

Subsurface soil was not evaluated for the representative receptors at EBG. Two COCs [arsenic and benzo(*a*)pyrene] were identified in subsurface soil for the other receptors evaluated.

The Level III BERA identified 15 COECs for subsurface soil (1 to 3 ft depth) at EBG.

8.3.3 Sediment

Sediment SRCs include explosives, metals, SVOCs (phenol/phthalates, and PAHs), VOCs, and a single occurrence of PCB-1254. Sampling results indicate the presence of low levels of only nitrobenzene, inorganic SRCs, and bis(2-ethylhexyl)phthalate at the inlet culverts, which suggest minimal influx of contaminants from upstream areas. The extent of explosives constituents in sediment downstream of the exit culvert was defined during the Phase II RI; however, some inorganics and PAHs were detected above background levels at the furthest downstream samples from the exit culvert.

No sediment COCs were identified for any exposure scenario or pathway for either the Hunter/Trapper or Fire/Dust Suppression Worker. Five COCs [antimony, arsenic, chromium, manganese, and benzo(*b*)fluoranthene] were identified in sediment for the other receptors evaluated.

The Level III BERA identified 58 COECs for sediment at EBG.

8.3.4 Surface Water

Explosives, propellants, metals, SVOCs, and VOCs were detected above background criteria in surface water samples at EBG. Surface water sampling results also indicate minimal influx of contaminants from upstream areas through the EBG inlet points, with only low concentrations of nitrocellulose at the east inlet and low concentrations of inorganic SRCs. Sampling of the stream downstream of the exit culvert indicated that no explosives, SVOCs, VOCs, pesticides, PCBs were not exiting the AOC under normal precipitation conditions.

One metal (arsenic) was identified as a carcinogenic COC for the Fire/Dust Suppression Worker exposed to surface water at EBG. No COCs were identified for the Hunter/Trapper. Risk-based RGOs were computed for arsenic at a TR of 10^{-5} and a THI of 1; however, the EPC used in this HHRA for arsenic was smaller than the most conservative risk-based RGO. Individual surface water sample data were not compared to the arsenic RGO. Two COCs (arsenic and manganese) were identified in surface water for the other receptors evaluated.

Nineteen COECs were identified for surface water in the Level III BERA.

8.3.5 Groundwater

Sampling of groundwater within source areas at EBG indicates minimal contamination related to AOC operations. Explosives were not detected in any of the groundwater wells installed and sampled during the Phase II RI. Concentrations of inorganic SRCs were similar in wells located within the principal source areas (e.g., the T-Area and the Track 49 embankment) and at both the up- and downgradient AOC boundaries. Low levels of SVOCs, one VOC, and one pesticide were detected in one to two wells. Few SVOC, VOCs, and pesticides/PCBs were present at detectable concentrations.

The representative receptors at EBG are not exposed to groundwater. One COC (arsenic) was identified in groundwater for the other receptors evaluated.

8.4 LESSONS LEARNED

A key project quality objective for the Phase II RI at EBG 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 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.

- Provisions for better delineating multi-increment irregularly shaped sampling areas in rough and heavily vegetated terrain should be incorporated into future project scoping efforts. Use of a backpack global positioning system, along with selected surveyed reference points. may be used to help better delineate such sampling areas.

- Any potential future application of multi-increment sampling techniques to subaqueous or extremely wet sediments must account for the fact that such samples may contain a high clay/silt content and do readily air dry within a short time frame. These characteristics make sieving and mixing of such samples difficult.

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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 EBG 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 remedy in place for the AOC by focusing the FS efforts to appropriate remedies based on site conditions and land use considerations. EBG is an ideal candidate for a focused FS approach because of the limited extent of contamination and the presence of the surface water basins would effectively preclude most, if not all, land uses other than maintenance and monitoring. For surface water and groundwater, the FS for EBG 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, in order to proceed with the FS phase. It is noted that low levels of explosives were detected in soil samples collected in the westernmost and northernmost sections of the Track 49 embankment; however, substantial data gaps have not been identified following completion of the Phase II RI.

Consensus on planned land use(s) to be evaluated in the focused FS will be required. 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 and attendant Land Use Controls Assurance Plan, 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.

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APPENDIX A

SOIL SAMPLING LOGS

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APPENDIX B

SURFACE WATER/SEDIMENT SAMPLING LOGS

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APPENDIX C

MONITORING WELL INSTALLATION AND DEVELOPMENT LOGS

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APPENDIX D

MONITORING WELL SAMPLING LOGS

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APPENDIX E

SLUG TEST LOGS AND SOLUTIONS

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APPENDIX F

PROJECT QUALITY ASSURANCE SUMMARY REPORT

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DATA QUALITY CONTROL SUMMARY REPORT

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LABORATORY ANALYTICAL RESULTS

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APPENDIX I

GEOTECHNICAL ANALYTICAL RESULTS

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FATE AND TRANSPORT MODELING RESULTS

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TOPOGRAPHIC SURVEY REPORT

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ORDNANCE AND EXPLOSIVES AVOIDANCE SURVEY REPORT

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APPENDIX M

INVESTIGATION-DERIVED WASTE MANAGEMENT REPORTS

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APPENDIX N

SUPPORTING INFORMATION FOR THE HUMAN HEALTH RISK ASSESSMENT AT ERIE BURNING GROUNDS

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APPENDIX O

ECOLOGICAL RISK ASSESSMENT DATA

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