

8. SUMMARY AND CONCLUSIONS

The LL 1 Phase II RI Report presents a detailed analysis of the environmental sample data collected during the Phase II RI field effort. The following sections present an overview of the major findings of the nature and extent of contamination, the modeling of contaminant fate and transport, and an assessment of the potential risk associated with contaminant exposure on human and ecological receptors.

The conclusions of this Phase II RI are presented by media with an emphasis on the degree of contamination and the associated potential risks to human receptors. The primary conclusion is that surface soil contamination is pervasive in the former production area and that within certain areas, direct and indirect exposure to the soil poses a significant risk in a variety of likely scenarios that have been considered for the future use of the LL 1 area. Subsurface soil, sediment, and groundwater present significantly lower potential risks in these scenarios. Surface soil in the former production area also represents the medium with highest potential risk to ecological (terrestrial) receptors at LL 1.

8.1 SUMMARY OF CONTAMINANT NATURE AND EXTENT ASSESSMENT

The Phase II RI evaluated the nature and extent of contamination in five media as follows: surface soil [from 0 to 0.3 m (0 to 1 ft) bgs], subsurface soil [from 0.3 to 1.0 m (1 to 3 ft) bgs], sediment, surface water, and groundwater. The surface and subsurface soils, sediments, and surface water were further divided into lateral aggregates based on building proximity and drainage area. The separation of the LL 1 surface soil and subsurface soil into aggregates allowed an examination of the data in terms of areas of similar operational history and, thus, similar contaminant impact. Sediment and surface water were grouped by drainage areas to facilitate the examination of contaminant spread by these media and to allow a focusing of the receptor exposure points for the baseline human health and screening ecological risk assessments. Groundwater, as an endpoint medium, was considered on an AOC-wide basis that still allowed a comparison of process area monitoring well samples to more distant wells. The results of this evaluation are summarized by medium and aggregate here.

8.1.1 Surface Soil

A total of 310 samples [from 0 to 0.3 m (0 to 1 ft)] were collected for the purpose of determining nature and extent of surface soil contamination across LL 1. Sampling locations were biased to the building perimeters and supplemented with the random grid samples.

At the former melt-pour complex (Buildings CB-4/4A, CA-6/6A, and settling basins) area:

- the immediate area around the Building CB-4A pad is the most heavily contaminated area at LL 1 with respect to concentrations of explosives, propellants, and metals. This distribution is likely the result of process operations and the practice of building washdowns to remove explosive accumulations from the buildings.
- HMX and RDX detections occurred frequently at the Building CB-4A pad but were not detected at the Building CB-4 pad.
- nitrocellulose was detected frequently across the entire load line, yet the propellants, nitroglycerine and nitroguanidine, were detected only once at LL 1, at stations near the Building CB-4 pad.

- the settling basins were less contaminated than the areas immediately near the former buildings, reflecting more containment of the explosives and no dispersion due to washdown.
- The melt-pour complex had the most frequent and highest detections of pesticides and PCBs. PCB-1254 was present in the surface soils with an average concentration of 70 mg/kg. The presence of these compounds is likely not directly related to melt-pour operations, but derived from related industrial activities (e.g., physical plant maintenance, paint, etc.) in the AOC.
- Buildings CB-4/-4A pads had the highest frequency of SVOC detections of any area in the load line. The majority of the SVOC detections throughout the LL 1 area were PAHs. The pervasiveness of these contaminants (PAHs) in industrial settings makes conclusions regarding the source problematic. The detections throughout the process area may reflect wind-borne transport or multiple sources.

At the fuze and booster installation (Building CB-10/13) area

- station LL1-ss-109, which is in a ditch south of the Building CB-13 pad, is a hot spot of metals and explosives contamination. The suspended contaminants, which were carried in the pink water generated during washdown of the buildings in this area, are the likely source of the ditch contamination. Additionally, demilitarization of primers occurred in the southeastern area of Building CB-13, which may have contributed to propellant contamination.
- the southeastern sides of the buildings are more heavily contaminated than any other area around the buildings, suggesting that this is where the washdown effluent was directed.

At the demilitarization processing area (Buildings CB-14, CB-15, and CB-17) area

- this area is not significantly contaminated with explosive compounds.
- this area also has less metals contamination when compared to the other building groupings in the load line. However, lead is elevated in some stations in both surface and subsurface soil.

At the storage and maintenance buildings at the start of the load line (Buildings CB-3, CB-801) and the Water Tower area

- the highest metals contamination in this area may be associated with slag on the railroad bed.
- residue generated during paint removal is the likely cause of elevated chromium, lead, and zinc in the Water Tower area. There is no PCB contamination associated with paint chips from the demolition of the Water Tower.
- this area is not significantly contaminated with explosive compounds.

In the Perimeter Area of the AOC

- there is minimal metals contamination (a few metals at 2 times background), indicating no widespread impact of LL 1 operations.
- there were no explosives or propellants detected in the perimeter area, indicating no significant migration of contamination from the major production areas to the outlying areas of the load line.

- the samples collected within the perimeter area indicate no additional source areas exterior to the main production area. The statistics-based gridding approach and use of randomly selected sample stations resulted in representative information on areas beyond the operational area of the load line.

8.1.2 Subsurface Soil

A total of 37 samples [from 0.3 to 0.9 m (1 to 3 ft)] were collected to determine the nature and extent of subsurface soil contamination and to assess vertical migration.

At the former melt-pour complex (Buildings CB-4/-4A and CA-6/-6A, and settling basins) area

- occurrences of explosive compounds in the subsurface soil are concentrated in the melt-pour area (including the former settling basin). The maximum concentration of any explosive in subsurface soil was near Building CA-6A, with TNT at 4,500 mg/kg. The maximum concentration of nitrocellulose (the only propellant identified in subsurface soils), at 29.3 mg/kg, was also encountered at this location.
- HMX and RDX are present at their maximum concentrations (8.1 and 58.0 mg/kg, respectively) at Building CB-4A. HMX was detected at this building in only two locations, and RDX was present at Buildings CB-4/-4A only.
- concentrations of metals in the subsurface are generally lower than in the surface soil, except where soil was disturbed during the demolition of buildings. Organic compounds were not analyzed in subsurface soil samples.
- the extent of vertical contaminant migration is limited due to the shallow depth of competent rock and to the low conductivity of the soils.

At the fuze and booster installation (Building CB-10/-13) area

- the sample from the ditch south of Building CB-13 (LL1-109) had the single detection of propellant (nitrocellulose at 29.3 mg/kg) in subsurface soil from this aggregate.
- the highest concentrations of cadmium, zinc, and lead also came from one sample at LL1-109. Barium, chromium, mercury, and selenium were only detected above background in the melt-pour area and at LL1-109. The highest concentrations of antimony, silver, and chromium in LL 1 subsurface soils came from LL1-109 (e.g., chromium estimated at 86 mg/kg versus background value of 27.2 mg/kg). Selenium occurrences above background appear to be associated with these buildings at station LL1-109.

At the demilitarization processing area (Buildings CB-14, CB-15, and CB-17)

- there was a single detection of explosives in subsurface soil from this aggregate. One sample at Building CB-17 (LL1-087) contained nitrocellulose at 8.8 mg/kg and TNT and 2,4-DNT at concentrations < 1 mg/kg.
- at LL1-087 at Building CA-17, cadmium, lead, and zinc were the sole exceedences of background values in the Water Tower area.

In the railroad bed area

- Track CB is generally free of explosives contamination, except for one laboratory detection at LL1-241 (0.17 mg/kg of 3-nitrotoluene). Two of 10 samples collected for field explosives analysis from Track CB had evidence of explosives, but only LL1-241 contained detectable quantities in the confirmatory laboratory analysis.
- LL1-244 and LL1-245 on Track CB are the only railroad bed samples that have detections of metals that exceed background. Cadmium and zinc were found above the background values in both samples.

8.1.3 Sediments

A total of 38 sediment samples [from 0 to 0.2 m (0 to 0.5 ft)] were collected at 32 locations during the Phase II RI to determine the nature and extent of contamination. Sample sites included Drainage A; Drainage B; Drainage C and Charlie's Pond; Drainages E/F/G and Criggy's Pond; the North Area channel; and off-AOC. Six off-AOC stations were sampled twice during the Phase II RI effort (September and November 2000). Ten of the Phase I RI stations were re-sampled during the Phase II RI.

- Ditch sediments near Buildings CB-13/-13B contain the greatest quantity of explosives, propellants, and TOC.
- Explosive contamination does not appear to have migrated far along drainages exiting LL 1. The source of all explosives in ditch and pond sediments is believed to be from pink wastewater discharged directly from the load line, rather than from migration of surface soil contamination.
- Metals were detected in all sediment samples but were concentrated and most abundant along Drainages A, C, E, and F. Metals detected in off-AOC areas were most likely transported to those locations in process-related effluents exiting the process area through Drainage C. However, the presence of metals in sediments at LL1-318, which is upstream of the confluence with LL 1 drainage ways, indicates that other areas at RVAAP may be contributing contaminants to downstream off-AOC locations.
- PCBs were detected at isolated locations within drainage ditches, indicating that erosion of surface soils has not dispersed PCBs across the AOC.

8.1.4 Surface Water

Fourteen surface water samples were collected from eight locations during the Phase II. Six of these stations were co-located with sediment samples, while the remaining two stations were collected from both Charlie's and Criggy's Ponds. Six surface water stations in off-AOC areas were sampled twice in order to more fully characterize potential impacts of LL1 on surface water quality as it exits the installation to the east.

- The maximum explosive concentration in surface water on-site (0.27 µg/L of 2,4-DNT) occurred in Drainage C. Explosive compounds were detected in one of the four samples in this drainage and in one of two samples in Drainage A. Explosive compounds were detected in only one of the off-AOC samples at very low concentrations (0.1 µg/L of 2,4-DNT). Variations in the concentrations between the two sampling rounds (e.g., detections at low levels versus non-detects) indicate the transient nature of the contamination in surface water.

- Metals were detected in all surface water samples but were most abundant at Charlie's Pond, which is at the AOC boundary along Drainage C, and at station LL1-318, which is upstream of the confluence with LL 1 drainage ways. The presence of metals in surface water at LL1-318 indicates that other areas at RVAAP may be contributing contaminants to downstream off-AOC locations.
- No SVOCs, VOCs, or PCBs/pesticides were detected in surface water within LL1 AOC. These compounds are most likely not migrating along drainage ways due to high sorption potential to soils and sediments, and the one minor detection in the off-AOC area is most likely due to contributions from other areas.

8.1.5 Groundwater

- Isolated detections and relatively low explosives concentrations in monitoring wells near the main process areas indicate that migration of explosives from soil to groundwater is minimal. Samples from monitoring wells LL1mw-064 and LL1mw-065, east-southeast of the AOC, contained no detectable explosive compounds.
- Monitoring wells within the main process areas appear to have been impacted by site-related metals contamination. However, detections of metals above background are generally not found in groundwater at the perimeter locations sampled.
- Zinc concentrations have increased for most monitoring wells in which zinc was detected between the 1999 and 2000 sampling events. No clear time patterns exist for other metals in groundwater.
- Minor detections of SVOCs and PCBs/pesticides in few monitoring wells near the main process areas indicate that migration of these contaminants from soil to groundwater is minimal.
- Three VOCs—chloroform, methylene chloride, and toluene—were detected in several monitoring wells. However, two of these compounds were also detected in trip blank samples; therefore, the presence of these VOCs may or may not be related to LL 1 activities.

8.1.6 Sanitary Sewer Surface Water and Sediment

Two water samples were collected from the sanitary sewer drain system, one from the northwest corner of LL 1, which is a major collection point for sanitary effluent from the load line, and the other from east of the melt-pour complex. Explosives were detected in low concentrations (<0.1 mg/L) in the sample from east of the melt-pour complex. Metals were detected in both water samples, but no background data set is available for comparison. The highest concentration detected was 16.1 mg/L for iron from the northwest corner of the load line. This location also showed very low estimated concentrations (<0.01 mg/L) of SVOCs.

Seven sediment samples were collected and analyzed from the sanitary sewers and storm drain inlets. Explosives and propellants were detected in all of the sediment samples, except one not sent to the fixed-base laboratory because the field screening showed non-detect for TNT/RDX. Cyanide was not detected in any sample, and hexavalent chromium was detected in only one sample at a concentration of 5.4 mg/kg. TAL metals were commonly detected in the sewer sediment samples. The highest inorganic contamination of many metals occurred in samples from manholes 208 and 213, corresponding to the melt-pour complex and an area adjacent to former Building CB-14, respectively.

Only two sediment samples—one from within the melt-pour complex and one adjacent to former Building CB-14—were analyzed for organic compounds. Isolated VOCs were detected at concentrations less than 0.01 mg/kg. PAHs were detected in both samples, with concentrations ranging from 0.41 to

25 mg/kg. Pesticides and PCBs were also detected in both samples. The pesticides were commonly used for insect control throughout RVAAP, but the specific sources of the PAHs are not known.

8.2 SUMMARY OF FATE AND TRANSPORT MODELING

Fate and transport modeling was used to simulate the vertical transport of contaminants from source areas to groundwater and horizontal transport within the groundwater system to receptor locations. The program, SESOIL, was used to predict the maximum concentration of leachate in the soil profile (ground surface to upper level of saturated soil zone) beneath the source areas. AT123D modeling was performed to predict the transient spread of a contaminant plume through the groundwater aquifer in the LL 1 area. The following primary conclusions can be drawn from this analysis.

- Modeling indicates some of the explosives compounds are expected to leach from the contaminated surface soils into the groundwater with predicted concentrations exceeding the groundwater RGOs in the source areas. However, the potential for off-AOC migration of these contaminants (via the groundwater pathway) at LL 1 is not significant. Migration of most of the constituents is attenuated because of moderate to high retardation factors.
- Metal, PCB, and PAH contaminants within the LL 1 subsurface soils are not expected to leach to groundwater beneath the sources within the modeled time frame of 1,000 years.
- The extensive system of storm and sanitary sewers represents a possible preferred migration pathway for water-borne contaminants. Leaks from the pipes may rapidly introduce contaminants from surface soil sources to groundwater.

8.3 SUMMARY OF THE BASELINE HUMAN HEALTH RISK ASSESSMENT

A BHHRA was conducted to evaluate risks and hazards associated with contaminated media at LL 1 for a number of potential future land use scenarios including National Guard use, Open Industrial, Open Recreational, and Open Residential. The most likely future receptors are the National Guard trainee, as well as a Hunter/Trapper, Security Guard/Maintenance Worker, and Industrial Worker. A Child Trespasser is also considered to be a potential receptor. The Open Residential scenario was evaluated as an upper-bound (i.e., worst-case) scenario for this BHHRA. To support the remedial alternative selection process, RGOs were developed for each chemical identified as a COC in the direct exposure pathways for this LL 1 BHHRA. Of the future land use scenarios and receptors evaluated, the National Guard training use, industrial use, and recreational use represent the most likely land use scenarios for RVAAP based on current information.

8.3.1 Soil

Water Tower and Perimeter Area. No chemical hazards >1 or risks $>10^{-6}$ were identified for direct exposure to soil for the eight receptors. Exposure to lead in surface soil at the Water Tower could result in a greater than 10% probability of exceeding acceptable fetal blood lead levels for the Hunter/Trapper, National Guard, Security Guard/Maintenance Worker, Industrial Worker, and On-Site Resident Farmer adult and exceeding target blood lead levels for the On-Site Resident Farmer child. Exposure to thallium in foodstuffs by the On-Site Resident farmer resulted in hazards >1 for the Water Tower.

Buildings CB-13 and CB-10 and Change Houses. No chemical hazards >1 were identified for direct exposure to soil by any of the seven adult receptor scenarios. A total HI of 3 was estimated for direct

exposure to soil by the On-Site Resident Farmer child at Buildings CB-13 and CB-10 primarily due to PCB-1254. PAHs, PCB-1254, and explosives (On-Site Resident Farmer only) were identified as COCs with risks between 10^{-6} and 10^{-4} at Buildings CB-13 and CB-10. Only benzo(a)pyrene was identified as a COC for direct contact with soil at the Change Houses. No hazards >1 or risks $>10^{-6}$ were identified for the Hunter/Trapper at these two EUs. Ingestion of foodstuffs by the On-Site Resident Farmer resulted in hazards >1 and risks $>10^{-4}$ for both of these EUs, with the primary contributors to hazard/risk being PAHs and PCB-1254.

Buildings CB-14, CB-17, and CA-15. No chemical hazards >1 were identified for six of the eight receptors (all but the On-Site Resident Farmer). PAHs, PCB-1254, and RDX were identified as COCs with risks between 10^{-6} and 10^{-4} for this EU. Hazards >1 and risks $>10^{-4}$ were identified for both direct and indirect exposure to surface soil by the On-Site Resident Farmer at Buildings CB-14, CB-17, and CA-15. COCs with risks between 10^{-6} and 10^{-4} for this receptor include PAHs, PCB-1254, and explosives. The only COC with a risk $>10^{-4}$ and hazard >1 for direct contact is PCB-1254. Ingestion of foodstuffs results in COCs (PAHs, PCB-1254, explosives, and metals) with risk $>10^{-4}$.

Buildings CB-3 and CB-801. No chemical hazards >1 were identified for the Child Trespasser, Hunter/Trapper, or Recreational receptor. PAHs and PCB-1254 were identified as COCs with risks between 10^{-6} and 10^{-4} for these receptors. The estimated total cancer risk for the National Guard and Industrial Worker scenarios is 1×10^{-4} at this EU, with PAHs and PCB-1254 identified as COCs with risks between 10^{-6} and 10^{-4} . Estimated total risks to the Security Guard/Maintenance Worker and On-Site Resident Farmer are $>10^{-4}$. COCs with risks between 10^{-6} and 10^{-4} include PAHs, PCB-1254, and explosives (On-Site Resident Farmer only). Benzo(a)pyrene was identified as the only COC with a risk $>10^{-4}$ for direct contact with surface soil by these receptors. COCs with risks $>10^{-4}$ for ingestion of foodstuffs by the On-Site Resident Farmer include PAHs and PCB-1254. Exposure to lead in surface soil by the On-Site Resident Farmer at Buildings CB-3 and CB-801 could result in a $\leq 11\%$ probability for fetal blood lead concentrations to exceed acceptable levels and a $<27\%$ probability for child blood lead concentrations to exceed target levels.

Buildings CB-4/-4A and CA-6/-6A. Chemical hazards >1 were identified for all receptors for direct exposure to surface soil. COCs with risks between 10^{-6} and 10^{-4} include PAHs, explosives, and dieldrin. The only COC with a hazard >1 and risk $>10^{-4}$ for direct contact with surface soil is PCB-1254. Hazards >1 were also identified for direct contact with subsurface soil for the National Guard, Industrial Worker, and On-Site Resident Farmer, primarily due to 2,4,6-trinitrotoluene. RDX was identified as a COC with a risk between 10^{-6} and 10^{-4} for the Industrial Worker and On-Site Resident Farmer. Hazards >1 and risks $>10^{-6}$ were also identified for ingestion of foodstuffs by the On-Site Resident Farmer, in particular, PAHs, explosives, PCB-1254, and dieldrin were identified as COCs with hazards >1 and/or risks $>10^{-4}$ for this scenario.

8.3.2 Surface Water and Sediment

- No hazards >1 were identified for the Child Trespasser, National Guard, or Recreator exposed to surface water or sediment at Outlet C and Charlie's Pond; off-AOC, Outlets D, E, and F, and Criggy's Pond; or Outlets A and B (sediment only). Arsenic was the only COC identified with a risk $>10^{-6}$ for these three receptors for all EUs, except Outlets A and B sediment where PAHs contribute to a total risk $>10^{-6}$.
- No chemical hazards >1 were identified for the Hunter/Trapper directly exposed to surface water or sediment in these EUs. Direct exposure to arsenic results in a risk $>10^{-6}$ for this receptor at off-AOC, Outlet C and Charlie's Pond, and Outlets D, E, and F and Criggy's Pond. Direct exposure to PAHs in sediment results in risk $>10^{-6}$ at Outlets A and B. Ingestion of fish from Outlet C and Charlie's Pond, and

off-AOC results in an HI ≥ 1 due primarily to manganese. Ingestion of fish by the Hunter/Trapper from off-AOC surface water results in a risk of 2×10^{-4} , primarily associated with bis(2-ethylhexyl)phthalate.

- Chemical hazards >1 and risks $> 10^{-6}$ were identified for the On-Site Resident Farmer exposed to surface water, sediment, and fish at Outlet C and Charlie's Pond and off-AOC, surface water and sediment at Outlets D, E, and F and Criggy's Pond, and sediment at Outlets A and B.
- Lead is a COPC in sediment at the Outlet C and Charlie's Pond, Outlets A and B, and Outlets D, E, and F and Criggy's Pond EUs. With the exception of the On-Site Resident Farmer, all adult receptors had probabilities of fetal blood lead concentrations lower than the acceptable levels of less than 5%. For the On-Site Resident Farmer adult, probabilities are less than 9% at Outlets A and B, less than 1% in Outlet C and Charlie's Pond, and less than 29% in Outlets D, E, and F and Criggy's Pond. For the On-Site Resident Farmer child, the estimated probabilities of exceeding the target blood lead level of concern are less than 1% at Outlet C and Charlie's Pond, 19% at Outlets A and B, and 66% at Outlets D, E, and F and Criggy's Pond.

8.3.3 Groundwater

- Risks and hazards were estimated for the National Guard and On-Site Resident Farmer scenarios for potable use of groundwater.
- Risks and hazards estimated for monitoring wells north and south of Criggy's Pond are below levels of concern (i.e., no HI >1 or risk $>10^{-6}$) for both receptors.
- A total HI of 1 was estimated for monitoring wells in the LL 1 building area for the National Guard scenario associated primarily with manganese. The total risk for this receptor (5×10^{-5}) falls within the range of 10^{-6} to 10^{-4} . See Section 6.6.4 for a discussion of background of metals.
- The HIs of 4 (adult) and 14 (child), due to naturally present manganese, and total risk (2×10^{-4}) exceed the acceptable risk ranges for the On-Site Resident Farmer scenario. The primary contributor to risk for both the National Guard and On-Site Resident Farmer scenarios are explosives; 4,4'-DDE; and chloroform. Arsenic also contributes significantly to the total risk to these receptors. See Section 6.6.4 for a discussion of background concentrations of metals.

8.4 SCREENING ECOLOGICAL RISK ASSESSMENT

The present SERA adheres to a process that includes problem formulation, followed by exposure assessment and effects assessment, and culminating in risk characterization with attention to uncertainties and summarization. The results of the SERA indicate that there are COPECs (PBT compounds and/or HQs >1) for soil at all the terrestrial EUs, for sediment at all five EUs, and for surface water at two of the three EUs. These results are summarized more thoroughly below.

8.4.1 Soil

The soil COPECs included many HQs greater than 1, as well as many PBT compounds. The soil COPECs included numerous inorganics, SVOCs and pesticides, PCBs, and several explosives. For soil, the HQs for Aroclor-1254 for owls, shrews, mice, and robins at EU CB-4, CB-4A, CA-6, and CA-6A and were the highest observed in the SERA. The HQs for iron for plants were the next highest, exceeding 2,000 at all six EUs. Several inorganics had HQs that exceeded 1 at all six EUs. Explosives were COPECs with HQs greater than 1 at two soil EUs: CB-3 and CB-801; and CB-4, CB-4A, and CA-6. The CB-4, CB-4A,

CA-6, and CA-6A EU had the highest number of soil COPECs. The large number of COPECs at most of the terrestrial EUs suggests that terrestrial ecological receptors are at risk from COPECs in surface soil.

8.4.2 Sediment

Of the five sediment EUs, the Outlets A and B channel, Outlet C channel and Charlie's Pond, and Outlets D, E, and F and Criggy's Pond contained the highest number of COPECs. The COPECs included inorganics, one pesticide compound, explosives, and SVOCs. The highest HQ (1410) was for 1,3,5-TNB in the Outlets A and B channel aggregate. Acenaphthene had the next highest HQ (104) at the Outlets A and B channel. The Outlets D, E, and F channel and Criggy's Pond aggregate had eight inorganic COPECs with HQs greater than 1, four of which were also PBT compounds. The North Area channel had no COPECs. The off-AOC aggregate had three COPECs, including 1,3-dinitrobenzene; arsenic; and copper.

8.4.3 Surface Water

Iron is a COPEC in the Outlet C channel and Charlie's Pond aggregate and in the off-AOC aggregate for aquatic biota, with HQs of 10 and 4, respectively. In the off-AOC aggregate, iron and manganese were a COPEC for mink, with an HQs of 2. The Outlets D, E, and F channel and Criggy's Pond aggregate had no COPECs for any of the aquatic receptors.

8.4.4 Summary of the Screening Ecological Risk Assessment

In summary, surface soil represents the medium with highest potential risk to ecological (terrestrial) receptors at LL 1. Sediments at the five sediment EUs had fewer COPECs than the soil EUs, but potential risks to sediment-dwelling biota were also indicated. The surface water at the three surface water EUs had few or no COPECs, but they presented a few HQs greater than 1. Thus, of the three media studied for this SERA, surface water appears to present the least amount of risk to ecological receptors. Extrapolation of the WBG biological field studies to the LL 1 AOC might help verify whether actual adverse impacts are or are likely to occur to ecological receptors at LL 1. The details of such extrapolation are being developed by USACE and Ohio EPA.

8.5 CONCEPTUAL SITE MODEL

The LL 1 CSM was described in Chapter 5.0 in terms of contaminant sources and site-related chemicals, hydrogeology, release mechanisms, and migration pathways. Modeling was performed using these elements to assess the likely fate and transport of contaminants leached from the surface soil areas into the groundwater system. The following is a summary of the CSM that includes

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

An illustrated version of the CSM is presented in Figure 8-1 to assist in visualizing the summary information.

8.5.1 Contaminant Source Areas and Release Mechanisms

LL 1 operated for most of its history as a process line for the melting and loading of TNT and Composition B into large-caliber shells with later operations related to demilitarization of the munitions.

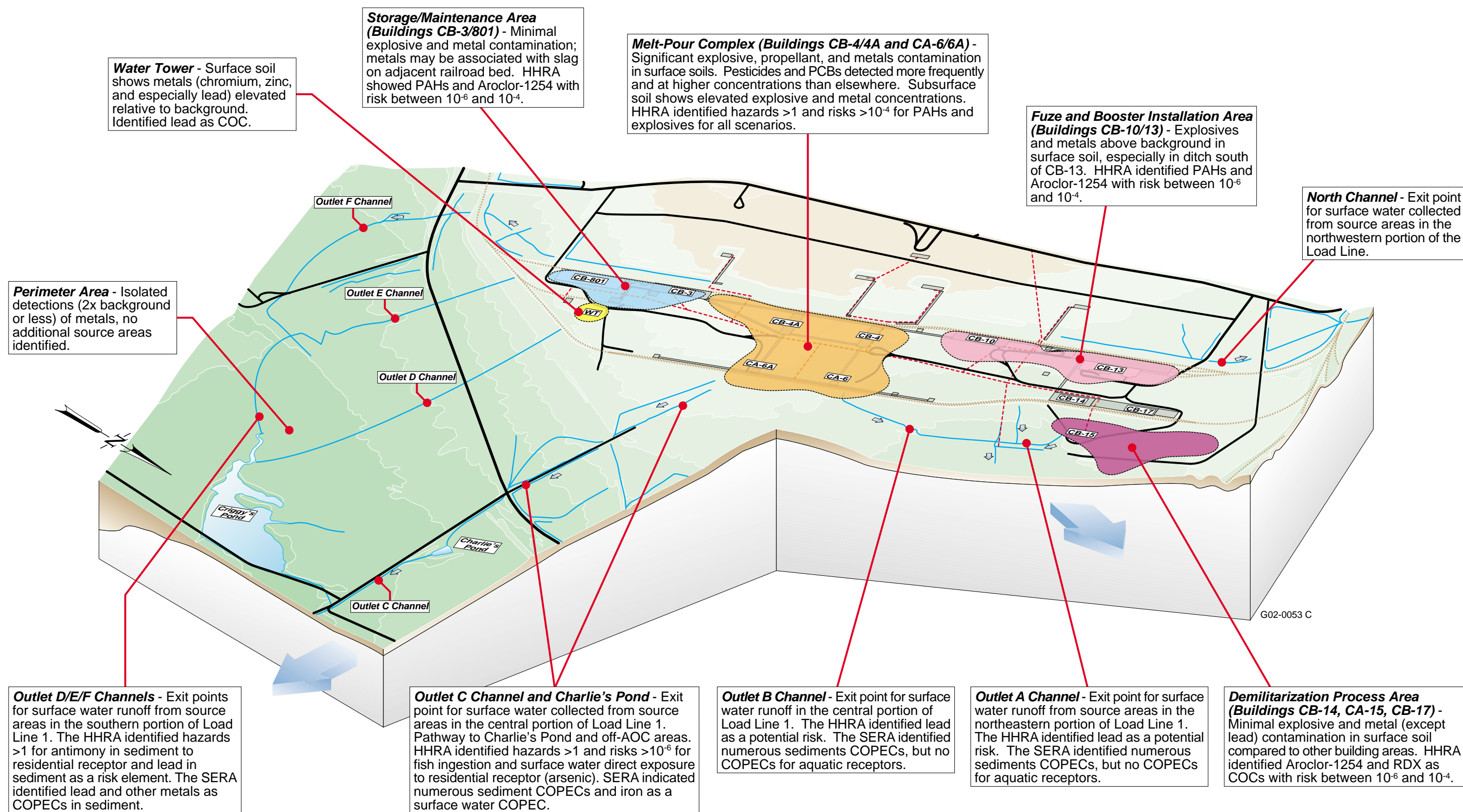


Figure 8-1. Conceptual Site Model for Load Line 1

These processes produced explosive dust, spills, and vapors that collected on the floors and walls of the former buildings. Periodically, the buildings were hosed down with water and steam cleaned. The liquid, containing TNT and Composition B, was collected in holding tanks, filtered, and pumped to one of four settling ponds. The current state of the former production area consists of many barren building pads, as demolition of the structures is mostly complete. As indicated on Figure 8-1, it is possible to outline sub-areas of the production area and to consider these sub-areas as contaminant source areas.

The Phase II RI sampling indicates the surface soil and subsurface soil (in certain areas) around the perimeter of the building pads are contaminated with explosive and propellant compounds and, thus, are the current primary source of contaminants (Figure 8-1). In addition, certain areas have metals in surface soil elevated relative to site background concentrations, particularly the area surrounding the former water tower. The crushed slag used throughout RVAAP for roads, railroad beds, and driveways may also be the source of certain elevated metals throughout the AOC. A suite of SVOCs, primarily PAHs, and a PCB (Aroclor-1254), are ubiquitous in the production area aggregates and are likely related to the industrialization of the site. Sampling of sediment within the sanitary and sewer line sediments indicates low levels of contamination are present and, thus, this medium is a possible source of contamination. Sampling of the open ditch near the former fuze and booster installation area (Buildings CB-10 and CB-13) in which washdown waters were directed indicates this channel is contaminated and is a likely source of explosives and metals contamination.

The primary mechanism for release of contaminants from the source areas is leaching of constituents via infiltration of rainwater through surface and subsurface soils. Modeling indicates some of the explosives compounds are expected to leach from the contaminated surface soil into the groundwater. The PAH and PCB/pesticide contaminants have long decay half-lives and high K_d values, thereby limiting their migration potential to groundwater. They are not expected to leach to groundwater beneath the sources within the modeled time frame (1,000 years).

The potential for contaminant release due to erosion of surface soil and overland transport to surface water drainages is minimal due the vegetative cover at the site. Sampling of drainage channels supports the conclusion that this mechanism is not a primary concern.

8.5.2 Contaminant Migration Pathways and Exit Points

The potential for lateral migration of leached contaminants from source areas via groundwater is limited due to sorption processes, contaminant solubility, and contaminant rate of decay. The low concentrations of explosives in downgradient monitoring wells versus higher concentrations in upgradient production area monitoring wells support this conclusion. The migration of contaminants to off-AOC is not supported by the groundwater sampling.

A possible second migration pathway is transport of contaminated sediments via the sanitary and sewer line pipes, which lead to the identified drainage outfalls at the production area boundary. This pathway's contribution of contaminants is thought to be minimal, as inspection of portions of the pipelines by video survey indicated very little sediment accumulation and that, overall, the integrity of the piping was not diminished. In addition, Phase II sampling results indicated that the channels downstream of the drainage outfalls are not contaminated.

8.5.3 Data Gaps and Uncertainties

The trends for contaminant levels in the production area monitoring wells are discussed in Chapter 4.0 and are based on limited sampling information. A more extensive data set for determination of the trends in groundwater contamination is needed and is considered a data gap. Such information would help to

validate the fate and transport modeling predictions and the likelihood of future groundwater contaminant migration. The assessment of deep groundwater at the site has not been performed and is considered a potential data gap. Characterization of deep groundwater may be necessary, if such data are required, in order to achieve remedial action objectives identified in the FS phase.

Potentiometric mapping indicates an eastward-directed gradient from the production area toward the AOC boundary. At present, monitoring well LL1mw-067 is positioned east and downgradient of the Buildings CB-14, CA-15, and CB-17 area and is useful for monitoring groundwater potentially impacted by this source area. Similar groundwater monitoring is needed for the area downgradient (east) of the melt-pour complex (Buildings CB-4/-4A and CA-6/-6A) to assess the impact to groundwater from this source area. The installation of a well in this area would fill this data gap.

An investigation into the possible sources of the PAHs and PCBs, especially Aroclor-1254, is necessary. It is likely that multiple sources are the reason for the ubiquitous distribution of these contaminants, yet if potential past uses or sources could be identified, the nature and extent of these contaminants may be more fully assessed.

8.6 CONCLUSIONS

The conclusions presented here by medium combine the findings of the contamination nature and extent and both risk assessments with fate and transport modeling.

8.6.1 Surface Soil

Surface soil in the six aggregates adjacent to the former process buildings represents the medium most impacted by contamination resulting from previous operations at LL 1. The areas of highest concentration are typically adjacent to the former building pads, with highly variable concentrations of contaminants at adjacent sample stations. Sampling of the AOC perimeter area did not indicate an impact from past operations in terms of contaminant extent.

Selected metals, such as copper, lead, and zinc, are elevated above background concentrations in the former process area, whereas chromium is elevated above background only in the Water Tower area, likely resulting from the residue generated during paint removal. Explosives and propellant detections and concentration ranges show a distribution that is related to the operational history and known source areas (process buildings), whereas the distribution of the PCB Aroclor-1254 and a suite of PAHs is more widely spread and not easily linked to a source.

Exposure to the surface soil, either through direct or indirect contact (e.g., foodstuffs), poses a hazard and potential risk for the seven scenario receptors within several of the aggregates inside the former process area. The contaminants creating a large risk (total ILCR $>10^{-4}$) or hazard (HI >1) are Aroclor-1254, benzo(a)pyrene, and 2,4,5-TNT. Exposure to lead in the surface soil of the Water Tower area and the Buildings CB-3 and CB-801 area could result in unacceptable fetal blood levels. The widespread distribution of Aroclor-1254 and the suite of PAHs will complicate remediation measures, especially any removal alternatives. Surface soil contamination also poses the highest potential risk to ecological receptors at LL 1.

The leaching of the explosives compounds from the contaminated surface soils into the groundwater is predicted (based on fate and transport modeling) to create concentrations exceeding the groundwater RGOs in the source areas; however, the potential of these contaminants to migrate off of the AOC via the groundwater pathway is minimized because of moderate to high retardation factors. In contrast, metals,

PCBs, and PAHs contaminants are not expected to leach to groundwater beneath the sources within a time frame of 1,000 years.

8.6.2 Subsurface Soil

The impact of process operations on LL 1 subsurface soil is minimal, except in the melt-pour area. In this area, explosive compounds (2,4,6-TNT and RDX) are concentrated in the interval (e.g., from 1 to 3 ft) above competent rock. Concentrations of metals in the subsurface soil are generally lower than in the surface soil, except where soil was disturbed during the demolition of buildings. Organic compounds were not analyzed in subsurface soil samples.

In the former melt-pour area (Buildings CB-4/-4A and CA-6/-6A), direct contact exposure to the explosives in subsurface soils for the National Guard, Industrial Worker, and On-Site Resident Farmer scenarios poses a hazard and potential risk. No risk or hazard is associated with the subsurface soil in the remaining two aggregates in which subsurface soil was collected.

8.6.3 Sediment and Surface Water

Process operations and washdown practices have contaminated the sediment in the ditch near Buildings CB-13/-13B, which contains high concentrations of explosives and propellants. Explosives contamination does not appear to have migrated far along drainages exiting LL 1.

A visual examination of storm and sewer lines indicated that accumulation of sediment within the pipes is minimal. Explosives and propellants were detected in manhole sediment samples along with PAHs, pesticides, and PCBs.

Direct contact with surface water in the Outlet C channel and Charlie's Pond, Outlets D, E, and F channels and Criggy's Pond, and the off-AOC aggregate has an associated potential risk and hazard for the On-Site Resident Farmer scenario due to the contaminants arsenic and bis(2-ethylhexyl)phthalate. Arsenic concentrations in these drainages were elevated above the background criterion and likely are related to historical LL 1 activities. Low and infrequent detections of bis(2-ethylhexyl)phthalate do not necessarily reflect legacy contamination, but may reflect sporadic laboratory-induced contamination. Ecological risk is confined to a few chemicals with relatively low risk.

Exposure to sediment within the Outlet A channel, Outlet B channel, the Outlets D, E, and F channels and Criggy's Pond, and Outlet C channel and Charlie's Pond aggregates presents a potential hazard or risk in the On-site Resident Farmer scenario. Aroclor-1254, benzo(a)pyrene, and arsenic are the contaminants of concern. Exposure of the On-Site Resident Farmer to lead in sediment in the Outlets D, E, and F channels and Criggy's Pond aggregate could result in unacceptable fetal blood lead concentrations. Exposure to the sediment contamination within the drainage channels poses a potential risk to sediment-dwelling biota.

8.6.4 Groundwater

The relatively low explosives concentrations in monitoring wells near the main process areas indicate that migration of explosives from soil to groundwater is minimal. The lack of explosives in monitoring wells at LL1mw-064 and LL1mw-065 indicates that migration in this direction is not occurring. Groundwater within the main process areas appears to have been impacted by site-related metals contamination. The fate and transport modeling conclusions are somewhat supported in that detections of metals above background are generally not found in groundwater at the perimeter locations sampled. In addition, the minor detections of SVOCs and PCBs/pesticides in the few monitoring wells near the main process areas indicate that migration of these contaminants from soil to groundwater is minimal.

The risk assessment of the exposure to groundwater for the National Guardsman and On-Site Resident Farmer scenarios indicates a potential risk does exist for explosive contaminants, the pesticide 4,4'-DDE, and chloroform. Exposure to off-AOC groundwater does not pose a risk in these scenarios.