6.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

6.1 INTRODUCTION

This Baseline Human Health Risk Assessment (BHHRA) documents the potential human health risks to humans resulting from contamination within the WBG at the RVAAP, Ravenna, Ohio. The WBG has been in operation since 1941 and consists of approximately 80.9 ha (200 acres). Recent activities were limited to a RCRA area at Burning Pad #37, an area of approximately 0.4 ha (1 acre). Prior to 1980, the burning was carried out primarily in four pits, pads, and sometimes on the roads. Although it is not known precisely how many pads were contained within the 80.9-ha (200-acre) unit, 70 burning pads have been identified from historical drawings and aerial photographs. This risk assessment is prepared as part of the Phase II RI report for the WBG.

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

The human health risk assessment methodology used in the WBG BHHRA is based on *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989c). Additional methodology has been taken from: *Risk Dermal Exposure Assessment: Principles and Applications* (EPA 1992a); *Human Health Evaluation Manual, Supplemental Guidance "Standard Default Exposure Factors*" (EPA 1991b); *Exposure Factors Handbook* (EPA 1989d); *Integrated Risk Information System* (EPA 1998a) (updated approximately monthly); and *Health Effects Summary Tables* (EPA 1997b) (updated approximately annually). The inorganic and organic SRCs found in the various media are quantitatively analyzed (when possible) to characterize the potential risks to human health from exposure to these contaminants. The results of the BHHRA are used to (1) document and evaluate risks to human health; (2) determine the need, if any, for remedial action; and (3) identify chemicals of concern (COCs) that require the development of chemical-specific remediation levels. The WBG Sitewide BHHRA uses both Phase I and Phase II data to evaluate potential risks from exposure to various media including surface soil, subsurface soil, sediment, groundwater, and surface water.

This risk assessment is organized into six major sections. Section 6.2 discusses the screenings used to formulate the SRC list (that is discussed in detail in Section 4.0) for each medium and shows how SRCs are screened by various methods to identify COPCs for the BHHRA. Section 6.3 presents the exposure assessment, performed to identify the exposure pathways by which a receptor may be exposed to contaminants and the resulting potential intakes. Section 6.4 presents the toxicity assessment for the COPCs. Section 6.5 presents the results of the risk characterization. Section 6.6 presents an assessment of uncertainties associated with characterizing risks, and Section 6.7 summarizes the risk conclusions.

6.2 DATA EVALUATION

This chapter describes the two-stage data evaluation process used to identify COPCs for WBG. SRCs are initially identified for each medium, based on WBG data from both Phase I and Phase II. From this list, COPCs are then determined for each medium, both on a site-wide basis (i.e., across the entire WBG AOC) and on a location-by-location basis (e.g., for each well location).

The purpose of the BHHRA data evaluation screens is to eliminate SRCs for which no further risk evaluation is needed. Section 6.2.1 presents the SRC selection process and the data assumptions used during that process. Section 6.2.2 provides the screening process by which COPCs are determined, as well as a discussion of the aggregated data for all media.

6.2.1 SRC Screens

This section describes the screening process used to determine SRCs and the data assumptions for this process.

6.2.1.1 SRC Screening Process

The general process for identifying SRCs involves four steps: initial data evaluation, background characterization, background comparison, and weight-of-evidence screening.

Analytical results are reported by the laboratory in electronic form and loaded into a WBG database. Site data are 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 reanalyses and dilutions are not included in the determination of SRCs for this risk assessment. Field screening data that were considered in the evaluation of nature and extent of contamination at the WBG 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 1 percent. A complete summary of data quality issues is presented in the Data Quality Assessment of this report (see Appendix E).

Results from the RVAAP background data collection are used to characterize background levels for the various media (see Section 4.1.2.2 for details on this characterization). Separate background criteria are established for surface soil, subsurface soil, sediment, surface water, and groundwater.

This background characterization is then used to determine if detected metals are site-related or naturally occurring. For each medium, the detected metal concentrations are compared to the background criteria (established in Section 4.1.2.2). (Note that only metals are compared to background criteria; organics are not compared to background) Decision criteria for determining above-background chemicals are:

- A metal is considered to be site-related if it is detected above the background criteria in more than 5 percent of the samples analyzed.

- A metal with less than 5 percent of the sample results detected above its background concentration is not considered to be site-related. Note that the results of a risk characterization that does not incorporate this screening criteria is also presented for surface soil and subsurface soil (the two media affected by this screen; refer to Sections 6.5.2.1.4.1 and 6.5.2.1.6.1).

Weight-of-evidence screens are also used, including:

- Chemicals that are detected in less than 5 percent of the samples analyzed are not considered to be site-related when the following criteria are met: (1) the chemical is detected infrequently in one or perhaps two media; (2) the chemical is not detected in any other sampled media or at high concentrations; and (3) there is no reason to believe that the chemical may be present. (Note that chemicals that are never detected are not SRCs). Note also that any explosive detected in any medium at WBG is considered to be site-related (i.e., the low frequency of detection screen is not applied to explosives at WBG, but is applied to other chemicals at WBG).

- Naturally occurring essential elements, including calcium, iron, magnesium, potassium, and sodium, are an integral part of the country's food supply, and are often added to foods as supplements. Thus, these essential elements are not considered to be site-related.

The above-mentioned screens are used to select SRCs for each medium for the AOC (see for example, **Tables 4-14 to 4-18** in Section 4.0). The BHHRA then uses data evaluation screens on these SRCs to identify human health COPCs (both on a site-wide aggregated basis, as well as on a location-by-location basis); refer to Section 6.2.3. For efficiency purposes, the results of both the SRC and COPC screens will be shown on the same table, for each medium (refer to Section 6.2.3).

6.2.2 SRC Screening Assumptions

The data set used to determine SRCs includes data collected from both Phase I and Phase II. Specific assumptions applied to these data can be found in Section 4.0 (Nature and Extent of Contamination). The following assumptions, used in the development of SRCs for the BHHRA, are noted:

- Physical chemical data (e.g., alkalinity, pH, etc.) are not considered to be SRCs (and, therefore, are not considered to be COPCs) for the AOC.

- Filtered data are not used in the determination of surface water SRCs (i.e., only unfiltered data are evaluated for surface water). Unfiltered data include both soluble and insoluble chemicals. These data represent untreated/unprocessed water drawn from a surface water sampling station. However, due to problems with the groundwater samples having high turbidity, filtered metals data for groundwater are used in this risk assessment (Mohr 1998). See Section 4.1.2.2 for a detailed discussion on filtered groundwater data.

- Soil data are subdivided into two data sets, based on sampling depths used for the WBG. Since soil data were generally collected in intervals of 0 to 0.6 m (0 to 2 ft), 0.6 to 1.2 m (2 to 4 ft), and 1.2 to 1.9 m (4 to 6 ft), the surface soil data set is comprised of data only from the 0 to 0.6 m (0 to 2 ft) interval. Subsurface soil data is comprised of all sample results from 0.6 m (2 ft) and below. However, since exposures to subsurface soil involve going through the surface soil in order to reach the subsurface soil, the subsurface soil data set for this BHHRA is comprised of all sample results from 0 to 1.9 m (0 to 6 ft). Consequently, data from the surface soil data set are compared against the surface soil background criteria, and data from the subsurface soil data set are compared against the subsurface soil background criteria.

SRCs are determined for each medium by using all available data after the data assumptions listed above are applied. The determination of COPCs follows for each medium.

6.2.3 COPC Screen

The purpose of the COPC screens is to eliminate SRCs for which no further risk evaluation is needed. This section describes the screening process, as well as the screening assumptions used in the process.

6.2.3.1 COPC Screening Process

The determination of COPCs is performed for each medium, first on an aggregate (AOC-wide) basis and then on a location-by-location basis (e.g., for each well location). This Section describes the data aggregation process and the specific screens applied to both the aggregate data sets and the location-by-location data sets.

6.2.3.1.1 Data aggregates versus locations-by-locations

Data aggregation is needed in order to identify reasonable areas over which exposure to a receptor may occur. It also gives a representative understanding of contaminant exposure concentrations over an area (as opposed to using a location-by-location approach). To support this evaluation, data from the entire WBG are

aggregated and used consistently for all media in this BHHRA. That is, for each medium, there is one aggregate, which consists of data from the entire WBG.

The purpose of the determination of COPCs on a location-by-location basis is to evaluate the spatial distribution of risks across the entire WBG site; this approach will allow for the evaluation of "hot spots" and aid in the determination of how data should be further evaluated. For this BHHRA each sampling station is evaluated in this location-by-location approach.

All subsequent screens are performed in order to determine COPCs, on both the aggregated data sets and on the location-by-location data sets, for each medium.

6.2.3.1.2 Risk screen

In identifying COPCs, environmental sampling results are compared to concentrations derived from EPA Region IX risk-based PRGs (EPA 1998b). PRGs, as used in this BHHRA, are chemical-specific concentration goals established for a specific land use and medium (e.g., residential exposure to soil) and are risk-based (EPA 1991c). Each PRG represents a cancer risk level or toxicity hazard quotient (HQ) level that is considered protective and conservative in early screening stages. The EPA Region IX risk-based PRGs are presented at a risk level of 1×10^{-6} and at a hazard level of 1.0. Since the desired screening levels are 1×10^{-7} for risk and 0.1 for hazards, 1/10 of the Region IX PRGs are actually used as the risk-based screening criteria.

The risk screens are applied to the various media as follows:

- For surface soil, subsurface soil, and sediment, a conservative screen is performed using $1/10^{th}$ of the EPA Region IX residential soil PRGs as the risk-based screening concentrations (RBSCs). For informational purposes only, data from these same three media are also compared against $1/10^{th}$ of the Region IX industrial soil PRGs.

- One-tenth of the EPA Region IX tap water PRGs are used as RBSCs for surface water screening.

- Groundwater data are compared against both $1/10^{th}$ of the EPA Region IX tap water PRGs and against federal drinking water MCLs.

EPA Region IX PRGs can be found on the EPA Region IX World Wide Web site (http://www.epa.gov/region09/waste/sfund/prg/index.html). Drinking water MCLs are obtained from *Drinking Water Regulations and Health Advisories* (EPA 1996c).

These risk screens are performed for SRCs both on an aggregate (i.e., AOC-wide) basis, as well as on a location-by-location basis, for each medium. Chemicals that are not SRCs are not considered for evaluation as COPCs. The maximum detected concentration across the aggregate (or at each location) for each medium is compared against the appropriate RBSCs. Criteria for determining COPCs are as follows:

- Chemicals with all nondetected concentrations across the aggregate (or at a particular location) are not considered as SRCs and, consequently, are not considered as COPCs. For example, if a groundwater chemical has nondetected concentrations for all samples for all wells, then this particular chemical is not considered a groundwater COPC. Similarly for the location-by-location analysis, if a subsurface soil chemical has nondetected concentrations at all depths for a particular location, then this particular chemical is not considered a COPC at this particular location.

- SRCs whose maximum detected concentration is below the screening values used for the medium are not considered as COPCs. For example, if the maximum detected concentration for a surface soil SRC falls below the residential soil RBSC (i.e., $1/10^{th}$ the EPA Region IX PRG), then this particular SRC is not considered a COPC.

- SRCs whose maximum detected concentration meet or exceed any screening value remain on the COPC list. For example, if a groundwater SRC's maximum detected concentration is below the RBSC (i.e., $1/10^{th}$ the EPA Region IX tap water PRG) but above the MCL, then this particular SRC remains on the groundwater COPC list.

- Detected SRCs without screening values remain on the COPC list. That is, SRCs without screening criteria will not be eliminated from the COPC list.

The COPCs are then classified as quantitative COPCs when EPA-approved toxicity information is available and are further evaluated by quantifying risks and hazards on both an aggregate and location-by-location basis. For a discussion of the risks and hazards, refer to Section 6.5. The COPCs are classified as qualitative when no toxicity information is available, meaning that risks/hazards cannot be quantified. Toxicity profiles are presented for both the quantitative and qualitative COPCs (see Section 6.8).

Since the emphasis in this BHHRA is on aggregated risks and hazards, the location-by-location COPCs are not provided in this BHHRA. Results of the location-by-location risks and hazards are, however, presented in graphical summaries (see **Figures J.1 to J.23**, which are discussed in Section 6.5.2.2).

Tables J.2.1 through J.2.5 (Appendix J) present the COPC screens on an aggregate basis for groundwater, surface water, sediments, surface soils, and subsurface soils, respectively. These tables include:

- summary statistics, including the frequency of detection, range of non-detected concentrations, range of detected concentrations, arithmetic average concentration, and upper 95 percent confidence limit (UCL_{95}) on the mean concentration;

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

- SRC determination;

- and final COPC status.

Table J.2.6 summarizes the results of the data screens and shows which chemicals will be addressed quantitatively and qualitatively for each medium. Those analytes determined to be qualitative COPCs from the aggregate-by-aggregate analysis will be evaluated qualitatively in Section 6.4.6. The quantitative COPCs for the aggregated data will be evaluated quantitatively (i.e., by calculating risks and/or hazards) in Section 6.5.

6.2.3.1.3 Essential human nutrients

Ubiquitous essential elements, including calcium, chloride, iron, magnesium, potassium, and sodium (EPA 1989c) are removed from further consideration during the SRC screening process (see Section 6.2.1.1). These chemicals are considered to be human nutrients essential to a well-balanced diet and, as such, are often added to foods as supplements. For this reason they are typically not considered "hazardous" to humans. Such chemicals are not addressed as COPCs in evaluating risks to human health in this BHHRA.

6.2.3.1.4 Screening for copper and lead

The absence of available toxicity information (that is, approved reference doses or slope factors) for copper and lead precludes quantifying human health risk calculations (see Section 6.5) for these two chemicals. However, several regulatory guidelines for evaluating these chemicals in relationship to their impact on human health are available.

The lead soil and sediment concentrations (see **Tables J.2.3 through J.2.5**) are compared to the lead soil screening guidance concentration of <400 mg/kg for residential soils (EPA 1994b). Copper and lead groundwater and surface water concentrations (see **Tables J.2.1 and J.2.2**) are compared to technology action levels of 1300 µg/L and 15 µg/L, respectively. These technology action levels are National Primary Drinking Water Regulations, from the EPA Office of Groundwater and Drinking Water (see the EPA World Wide Web site http://www.epa.gov/OGWDW/wot/appa.html).

Results of these copper and lead comparisons are:

- All copper concentrations in groundwater (maximum detected concentration of 9.8 µg/L) and in surface water (maximum detected concentration of 5.5 µg/L) are below the technology action level of 1300 µg/L.

- Lead is not detected in surface water and therefore was not compared to its technology action level; the maximum detected concentration for lead in groundwater (3.1 µg/L) is below the technology action level of 15 µg/L.

- Lead concentrations in surface soils (as high as 2200 mg/kg) are above the residential screening value of 400 mg/kg.

- Lead concentrations in subsurface soils (maximum detect of 105 mg/kg) are all below the residential screening value of 400 mg/kg.

- Lead concentrations in sediments (maximum detect of 40.1 mg/kg) are well below the residential screening value of 400 mg/kg.

Because lead's maximum concentration in surface soil exceeds the residential soil screening guidance concentration, this metal is considered to be a COPC. However, as stated earlier, due to a lack of toxicity values, risks cannot be quantified for lead. See also Section 6.8.1, which includes the toxicity profile for lead. Copper is not considered to be a COPC for groundwater or surface water since all copper concentrations are below the technology action level.

6.2.3.2 COPC Screening Assumptions

The data set of SRCs used for the determination of RVAAP/WBG human health COPCs have specific assumptions applied related to toxicity. The following assumptions are made in the process of screening to determine COPCs:

- Total chromium as a metal is evaluated conservatively by screening its detected concentrations against $1/10^{th}$ the EPA Region IX PRGs for hexavalent chromium. This is a conservative assumption since Chromium VI is not analyzed for and is therefore not a SRC. Also, the fact that hexavalent chromium is more toxic than trivalent chromium and is a less commonly occurring form of the metal adds to this conservative assumption.

- Thallium as a metal is evaluated conservatively by screening its detected concentrations against $1/10^{th}$ the EPA Region IX PRGs for thallium carbonate, the form of thallium with the most conservative RBSCs.

6.3 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to determine or estimate the magnitude, frequency, and duration of potential human exposure to COPCs. The four primary steps of the exposure assessment are to: (1) characterize the exposure setting to identify the potentially exposed human receptors, their activity patterns, and any other characteristics that might increase or decrease their likelihood of exposure; (2) identify each exposure pathway by which a receptor may be exposed to the contaminants (e.g., swimming, private well use); (3) identify the concentrations of COPCs to which the receptors may be exposed; and (4) quantify the receptor intake. 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 during risk characterization (Section 6.5).

This section is organized in the following manner:

- identify the exposure setting, including defining current and future potential land use and human receptors;
- identify exposure pathways associated with each land use/receptor combination;
- identify the exposure models and model parameter values used to quantify the potential exposures to each identified receptor; and
- quantify potential intakes.

6.3.1 Exposure Setting

The RVAAP installation is located in two counties of northeastern Ohio, Portage County and Trumbull County, with a majority of the facility lying in Portage County. According to the 1990 Census, the total population of Portage and Trumbull counties was 142,585 and 227,813, respectively. The largest population centers in the area are the town of Ravenna (population 12,069), located approximately 2 miles to the west, and Newton Falls (population 4866), located approximately 1 mile to the southeast.

Approximately 55 percent of Portage County is either woodland or farmland (Portage County Soil and Water Conservation District Resources Inventory 1985; Census Bureau 1992). To the south of the facility is the Michael J. Kirwan Reservoir, which serves as a potable water source and is used for recreational purposes. The Reservoir is south of the site, across State Route 5. The Reservoir is fed by the West Branch of the Mahoning River, which flows south along the western edge of the installation. Hinkley Creek flows south across the western portion of the facility and eventually flows into the West Branch of the Mahoning River. The other major surface drainages at RVAAP, Sand Creek, and the South Fork of Eagle Creek, exit the facility property and eventually flow east to the Mahoning River.

6.3.1.1 Land Use

The land use immediately surrounding the facility is primarily rural. Residential groundwater use occurs outside of the facility. Residential wells in the vicinity of the RVAAP are completed in both the unconsolidated unit and bedrock.

Land use within the facility is restricted access. In 1993, the land use changed from "maintained caretaker" status to "inactive-modified (un-maintained) caretaker" status (Department of the Army, Environmental Assessment, 1993). This new status indicated that the facility was no longer needed to mobilize for war efforts. The only remaining federally mandated mission for the facility was identified as ammunition and bulk explosives storage. Funding decreased for building maintenance and maintenance activities such as mowing. WBG, which lies within the center of the facility, is outside of any of the proposed ammunition storage areas. Site workers infrequently visit the WBG, e.g., to status beaver dams; however, mowing no longer takes place. Current on-site use of surface water is limited to use by wildlife. There are no groundwater/production wells located at the WBG.

The Ohio Army National Guard (OHARNG) operates the Ravenna Training and Logistics Site (RTLS) on the eastern portion of the RVAAP. Until recently, the OHARNG leased 364 ha (900 acres) within RVAAP from the federal government along the eastern boundary of the facility and in the southeast–central portion of the facility along Newton Falls Road (see **Figure 6-1**). Once the RVAAP status changed from "Maintained" to "Modified" caretaker status, the OHARNG began negotiations with the Army IOC to acquire more land at the facility. This transfer of land from the Army IOC to the OHARNG became official in May of 1999. This transfer included approximately 7,049 ha (17,419 acres), leaving 1,619 ha (4,000 acres) under the control of the IOC, including 41 ha (100 acres) considered to be AOCs. Figure 6-1 shows approximately the current status of all land at the facility. As indicated on the figure, WBG is located within the land area retained by the Army IOC. As part of the land transfer, the Army IOC retained access to all roads and railways. The IOC retains responsibility for all salvage, demolition, and environmental remediation activities within the contaminated areas.

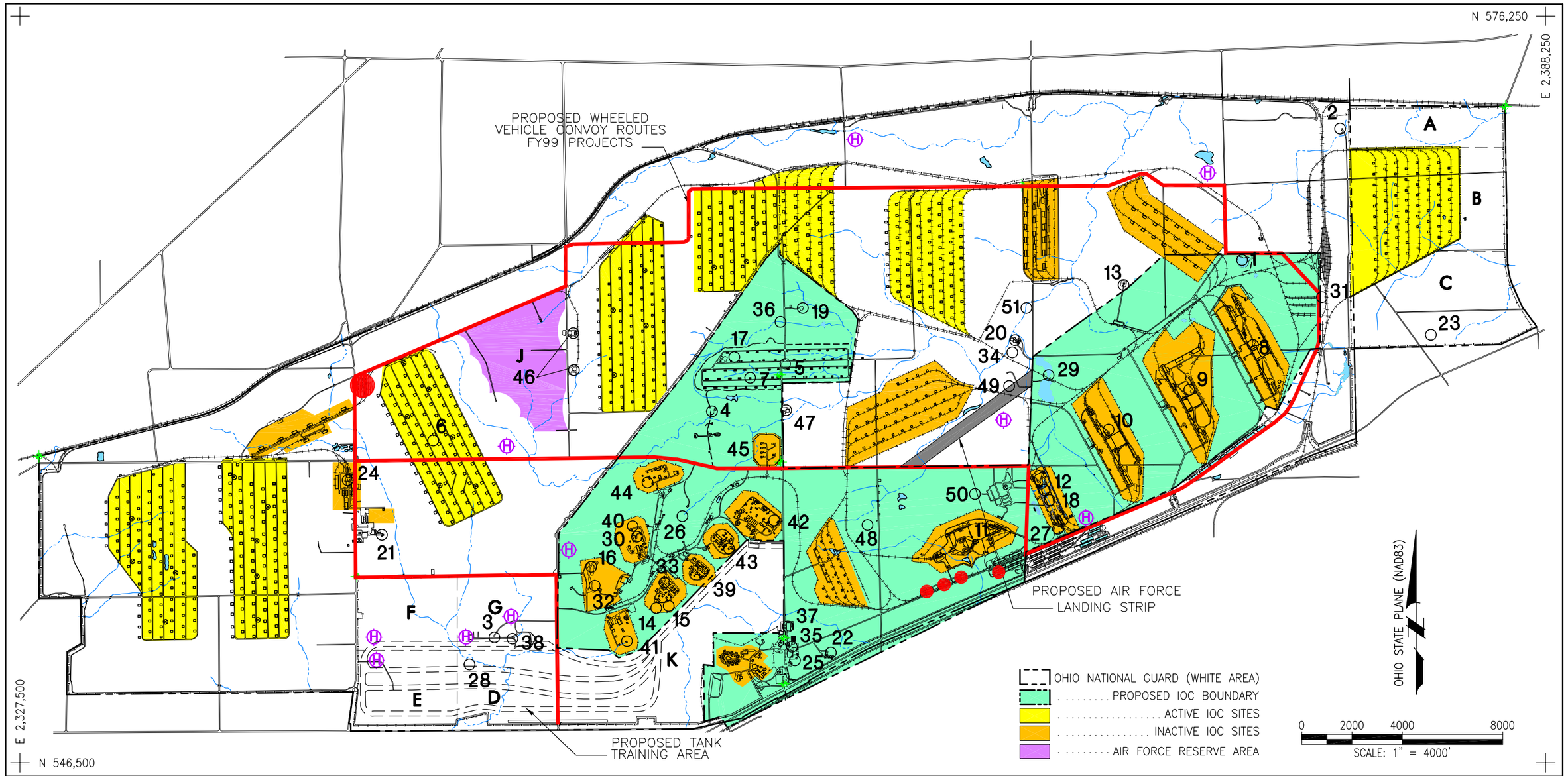
As part of acquiring the RVAAP lands, the OHARNG has taken on the forestry and land management responsibilities at the facility. This includes, but is not limited to, managing deer hunts and other animal harvesting activities (e.g., trapping and fishing); forestry activities; and nature study activities, such as academic research, bird studying and watching, tours, field trips, etc. These activities currently occur in most of the AOCs, as well as outside the AOCs.

Also noted on the figure are areas within the newly acquired OHARNG areas that are either leased back to the Army for use as continued munitions storage or are identified areas that will not be utilized by the OHARNG because of the desire to preserve natural areas [e.g., approximately 81 ha (200 acres) north of Smalley Road deemed 'pristine hemlock forest and gorge,' and 344 ha (850 acres) of wetlands]. In addition, the OHARNG is identifying naturally or culturally sensitive areas on the facility that will not be used for training.

Based on these factors, much of the newly acquired land will not be usable for training purposes. This results in a continued shortfall of land for training purposes. Because of this, the OHARNG has expressed a strong interest in acquiring land within the IOC "contaminated areas" as soon as the AOCs are remediated to an acceptable degree. Much of the lands within the contaminated areas are the most suitable areas for developing National Guard training operations. WBG is one of these areas. Based on an interview with Lieutenant Colonel Tom Tadsen (July 7, 1998), OHARNG officer in-charge of the RTLS, WBG would be suitable for helicopter operations such as medical evacuation drills, as well as other potential operations.

Development of RVAAP for guard training purposes will occur over several years. Factors that will go into this development will include:

- IOC ammunition storage needs;
- building salvage and demolition plans and schedules;
- preservation of sensitive areas (e.g., wetlands);
- OHARNG training needs and planning;



LEGEND OF SITES:

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 BLDG 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 BLDG 1200 AND DILUTION/SETTLING POND
14 LOAD LINE 6, EVAPORATION UNIT
15 LOAD LINE 6, TREATMENT PLANT
16 QUARRY LANDFILL/FORMER FUZE & BOOSTER BURNING PITS
17 DEACTIVATION FURNACE
18 LOAD LINE 12 PINK WASTE WATER TREATMENT
19 LANDFILL NORTH OF WINKLEPECK BURNING GROUND
20 SAND CREEK SEWAGE TREATMENT PLANT
21 DEPOT SEWAGE TREATMENT PLANT
22 GEORGE ROAD SEWAGE TREATMENT PLANT
23 UNIT TRAINING SITE WASTE OIL TANK
24 RESERVE UNIT MAINTENANCE AREA WASTE OIL TANK
25 BLDG 1034 MOTOR POOL WASTE OIL TANK
26 FUZE BOOSTER AREA SETTLING TANKS
27 BLDG 854–PCB STORAGE
28 MUSTARD AGENT BURIAL SITE
29 UPPER AND LOWER COBBS 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 BUILDING'S 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

○ 51 IOC ENVIRONMENTAL AOC
PROPOSED CONVOY ROUTES
Ⓗ PROPOSED HELICOPTER LANDING ZONES
DEFENSE LOGISTICS AGENCY (DLA) STORAGE

US Army Corps of Engineers Louisville District

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

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
LAND USE MAP

DRAWN BY:	REV. NO./DATE:	CAD FILE:
P. HOLM	REV. 1/07–20–99	98026/DWGS/D23IOC

Figure 6-1. RVAAP Proposed Land Use Map

- schedules for environmental remediation of the AOCs; and
- funding available to IOC and the OHARNG for all of the above activities.

Based on these considerations and the complexity of addressing all of the above issues, the most likely near-term (from 2 to 10 years) use of the WBG area is "institutional maintained." The most plausible long-term land use is a combination of OHARNG training use and controlled recreational use.

Even though there is a high potential that near-term land use will become the actual long-term use of the land, this BHHRA also will evaluate additional potential future land uses that reflect more open use of the land, including open industrial, open recreational and open residential. The land uses that will be evaluated as part of the BHHRA are listed in **Table 6-1**.

Table 6-1. Potential Receptors for the WBG BHHRA

Land Use Designation	Description	Potential Receptors
Modified Caretaker – Managed Recreational	Activities that are currently taking place at the sites, including light maintenance and controlled land management (e.g., controlled hunting and recreational activities)	Government contractors (e.g., security guards or maintenance workers) Permitted hunters, trappers, and nature study participants Trespassers
National Guard – Managed Recreational	National Guard training activities and controlled recreational activities (e.g., controlled hunting)	National Guard personnel and trainees Permitted hunters, trappers, and nature study participants Trespassers
Open Recreational	Uncontrolled recreational activities	Hunters, trappers, and nature study participants
Open Industrial	Commercial industrial operations	Full-time industrial workers
Open Residential	Residential housing and farming	On-site resident farmer (child and adult)

6.3.1.2 Receptors

Potential human receptors have been identified for each of the identified land use scenarios in **Table 6-1**. Note that in several cases a land use designation results in multiple types of activities occurring simultaneously (e.g., National Guard training and recreational activities could both occur under the "National Guard – Managed Recreational" scenario).

6.3.2 Exposure Pathways

An exposure pathway is made up of the following components:

- source;
- release mechanism (e.g., leaching, volatilization);
- transport pathway;
- exposure point;
- exposure route; and
- receptor.

Figure 6-2 shows the potential exposure pathways for the WBG HHBRA for each identified land use scenario. The exposure parameters for each receptor are shown in **Table 6-2**. Provided below is a discussion of each land use/receptor/pathway combination. Release mechanisms and transport pathways are discussed in detail in Chapter 7.0 of this report.

6.3.2.1 Modified Caretaker – Managed Recreational

This land use scenario describes the current use of the land. Decision-making using this scenario would imply that no land use changes would occur in the foreseeable future. Current IOC personnel at the site were interviewed to define receptor-exposure activities under the existing scenario (**Table 6-3**) (interview with Tim Morgan, IOC Forester, July 8, 1998).

Since the exposure frequencies and durations associated with the authorized uses are significantly greater than the unauthorized uses, the unauthorized receptors will not be evaluated quantitatively in the risk assessment.

Security Guard – Maintenance Worker

Current government activities at the WBG are limited to maintenance activities (including checking on beaver damage) and environmental remediation activities. Ongoing demolition activities at the RVAAP do not take place within WBG, nor do mowing activities. Security patrols occur daily across the site, but not within WBG; patrolmen usually remain within their vehicles during these patrols. Although the security guard is not currently exposed to contaminated media in WBG on a daily basis, the potential exposure for this receptor will be evaluated in this BHHRA. Therefore, as a worst-case assumption, it is assumed that a security guard would leave his or her vehicle on a daily basis, and be exposed to surface soil, sediment, and surface water. Parameter values used to assess this receptor in the BHHRA are found in **Table 6-2**.

Hunter/Trapper

Permitted deer and waterfowl hunting takes place every fall at the RVAAP. It is managed jointly by the facility staff and the State Division of Wildlife. According to Tim Morgan, IOC Forester, deer hunting takes place during 6 to 12 weekends per year. Hunts do occur in WBG and most other AOCs. Hunters are escorted and allowed a maximum of two deer per year. It is possible that a single hunter could participate in hunts over several years. Hunters could be exposed to COPCs via direct contact with soil (including inhalation of fugitive dusts), as well as through the ingestion of deer meat.

Waterfowl hunting currently takes place in 10 designated areas, none of which are in the boundaries of the WBG. Hunters may be exposed to surface water and sediments plus soils.

Trapping takes place three months of the years from November through January, primarily to control beaver and raccoon populations. Trapper pairs are assigned 0.4 to 1.6 ha (1 to 4 acres) and are allowed to check and set traps daily, although most do not. Traps are generally set near ponds (near existing dams) and along roadsides. According to Tim Morgan, IOC Forester, the most common catches include beaver, mink, muskrat, weasel, raccoon, possum, rabbit, and squirrel. In 1997, 450 raccoon, 74 beaver, and 300 muskrat were trapped, as well as additional species.

Pathway	Modified Caretaker – Managed Recreational			National Guard – Managed Recreational			Open Recreational	Open Industrial	Open Residential[a]	
	Security Guard (1)	Hunter/ Trapper (2)	Trespasser (3)	National Guard (4)	Hunter/ Trapper (2)	Trespasser (3)	Recreator (5)	Industrial Worker (6)	Resident Farmer – Adult (7)	Resident Farmer – Child (8)
Surface Soil										
Incidental Ingestion	●	●	●	●	●	●	●	●	●	●
Dermal Contact	●	●	●	●	●	●	●	●	●	
Inhalation of VOCs and dust	●	●	●	●	●	●	●	●	●	
Subsurface Soil										
Incidental Ingestion				●				●	●	●
Dermal Contact				●				●	●	
Inhalation of VOCs and dust				●				●	●	
Sediment										
Incidental Ingestion		●	●	●	●	●	●		●	●
Dermal Contact		●	●	●	●	●	●		●	
Inhalation of VOCs and dust		●	●	●	●	●	●		●	
Surface Water										
Incidental ingestion while swimming		●	●	●	●	●	●		●	
Dermal contact while swimming		●	●	●	●	●	●		●	
Inhalation of VOCs		●	●	●	●	●	●		●	
Groundwater										
Ingestion				●					●	
Dermal Contact				●					●	
Inhalation of VOCs				●					●	
Foodstuff										
Ingestion of venison, game		●			●				●	
Ingestion of beef, pork									●	
Ingestion of milk products									●	●
Ingestion of vegetables									●	
Ingestion of fish		●			●				●	

[a] A conservative approach is taken to evaluate the open residential land use. In most cases, since the adult farmer produces larger risks and hazards than the child farmer, the adult is predominantly evaluated. In scenarios where the child receptor results in greater exposures than the adult receptor, the child is also evaluated. Consequently, the noncarcinogenic effects for a child and adult are evaluated for soil/sediment ingestion, as well as for the ingestion of milk products (the child ingestion rates are higher than the adult ingestion rates for these exposures). The carcinogenic effects for these exposures are evaluated using a weighted average of the child and adult parameter values (which results in a larger exposure than evaluating only the adult).

Figure 6-2. Site Conceptual Exposure Model for WBG

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Pathway								
Surface Soil								
Incidental ingestion								
Soil ingestion rate (Adult)	kg/day	0.0001[a]	0.0001[a]	NA	0.0001[a]	0.0001[a]	0.0001[a]	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	0.0002[a]	NA	NA	NA	0.0002[a]
Exposure time	hours/day	1[b]	2[b]	1[b]	8[b]	1[b]	NA	NA
Exposure frequency	days/year	250[a]	90[b]	24[b]	180[b]	75[b]	250[a]	350[a]
Exposure duration (Adult)	years	25[a]	30[b]	NA	25[b]	30[a]	25[a]	24[a]
Exposure duration (Child)	years	NA	NA	6[a]	NA	NA	NA	6[a]
Body weight (Adult)	kg	70[a]	70[a]	NA	70[a]	70[a]	70[a]	70[a]
Body weight (Child)	kg	NA	NA	15[a]	NA	NA	NA	15[a]
Carcinogen averaging time	days	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]
Noncarcinogen averaging time (Adult)	days	9125[a]	10950[a]	NA	9125[a]	10950[a]	9125[a]	8760[a]
Noncarcinogen averaging time (Child)	days	NA	NA	2190[a]	NA	NA	NA	2190[a]
Fraction Ingested	unitless	1[b]	1[b]	1[b]	1[b]	1[b]	1[b]	1[b]
Conversion Factor	days/hour	0.042	0.042	0.042	0.042	0.042	NA	NA
Dermal contact								
Skin area	m^2/event	0.316[d]	0.53[e]	0.815[f]	0.316[d]	0.53[e]	0.316[d]	0.53[e]
Adherence factor	mg/cm^2	1[c]	1[c]	1[c]	1[c]	1[c]	1[c]	1[c]
Exposure frequency	events/year	250[a]	90[b]	24[b]	180[b]	75[c]	250[a]	350[a]
Exposure duration	years	25[a]	30[b]	6[a]	25[b]	30[a]	25[a]	30[a]
Body weight	kg	70[a]	70[a]	15[a]	70[a]	70[a]	70[a]	70[a]
Carcinogen averaging time	days	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]
Noncarcinogen averaging time	days	9125[a]	10950[a]	2190[a]	9125[a]	10950[a]	9125[a]	10950[a]
Conversion Factor	($kg\text{-}cm^2$)/($mg\text{-}m^2$)	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	20[a]	20[a]	20[a]	20[a]	20[a]	20[a]	20[a]
Exposure time	hours/day	1[b]	2[b]	1[b]	8[b]	1[b]	NA	NA
Exposure frequency	days/year	250[a]	90[b]	24[b]	180[b]	75[c]	250[a]	350[a]
Exposure duration	years	25[a]	30[b]	6[a]	25[b]	30[a]	25[a]	30[a]
Body weight	kg	70[a]	70[a]	15[a]	70[a]	70[a]	70[a]	70[a]
Carcinogen averaging time	days	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]	25550[a]
Noncarcinogen averaging time	days	9125[a]	10950[a]	2190[a]	9125[a]	10950[a]	9125[a]	10950[a]
Conversion Factor	days/hour	0.042	0.042	0.042	0.042	0.042	NA	NA
Subsurface Soil								
Incidental ingestion								
Soil ingestion rate (Adult)	kg/day	NA	NA	NA	0.0001[a]	NA	0.0001[a]	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	NA	NA	NA	NA	0.0002[a]
Exposure time	hours/day	NA	NA	NA	8[b]	NA	NA	NA
Exposure frequency	days/year	NA	NA	NA	28[b]	NA	250[a]	350[a]
Exposure duration (Adult)	years	NA	NA	NA	25[b]	NA	25[a]	24[a]
Exposure duration (Child)	years	NA	NA	NA	NA	NA	NA	6[a]
Body weight (Adult)	kg	NA	NA	NA	70[a]	NA	70[a]	70[a]
Body weight (Child)	kg	NA	NA	NA	NA	NA	NA	15[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	25550[a]	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	NA	NA	9125 [a]	NA	9125 [a]	8760 [a]
Noncarcinogen averaging time (Child)	days	NA	NA	NA	NA	NA	NA	2190[a]
Fraction Ingested	unitless	NA	NA	NA	1[b]	NA	1[b]	1[b]
Conversion Factor	days/hour	NA	NA	NA	0.042	NA	NA	NA
Dermal contact								
Skin area	m^2/event	NA	NA	NA	0.316[d]	NA	0.316[d]	0.53[e]
Adherence factor	mg/cm^2	NA	NA	NA	1[c]	NA	1[c]	1[c]
Exposure frequency	events/year	NA	NA	NA	28[b]	NA	250[a]	350[a]
Exposure duration	years	NA	NA	NA	25[b]	NA	25[a]	30[a]
Body weight	kg	NA	NA	NA	70[a]	NA	70[a]	70[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	25550[a]	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	9125[a]	NA	9125[a]	10950[a]
Conversion Factor	(kg-cm^2)/(mg-m^2)	NA	NA	NA	0.01	NA	0.01	0.01

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	NA	NA	NA	20[a]	NA	20[a]	20[a]
Exposure time	hours/day	NA	NA	NA	8[b]	NA	NA	NA
Exposure frequency	days/year	NA	NA	NA	28[b]	NA	250[a]	350[a]
Exposure duration	years	NA	NA	NA	25[b]	NA	25[a]	30[a]
Body weight	kg	NA	NA	NA	70[a]	NA	70[a]	70[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	25550[a]	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	9125[a]	NA	9125[a]	10950[a]
Conversion Factor	days/hour	NA	NA	NA	0.042	NA	NA	NA
Sediment								
Incidental ingestion								
Soil ingestion rate (Adult)	kg/day	NA	0.0001[a]	NA	0.0001[a]	0.0001[a]	NA	0.0001[a]
Soil ingestion rate (Child)	kg/day	NA	NA	0.0002[a]	NA	NA	NA	0.0002[a]
Exposure time	hours/day	NA	2[b]	1[b]	8[b]	1[b]	NA	NA
Exposure frequency	days/year	NA	90[b]	24[b]	28[b]	75[c]	NA	350[a]
Exposure duration (Adult)	years	NA	30[b]	NA	25[b]	30[a]	NA	24[a]
Exposure duration (Child)	years	NA	NA	6[a]	NA	NA	NA	6[a]
Body weight (Adult)	kg	NA	70[a]	NA	70[a]	70[a]	NA	70[a]
Body weight (Child)	kg	NA	NA	15[a]	NA	NA	NA	15[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	10950[a]	NA	9125[a]	10950[a]	NA	8760[a]
Noncarcinogen averaging time (Child)	days	NA	NA	2190[a]	NA	NA	NA	2190[a]
Fraction Ingested	unitless	NA	1[b]	1[b]	1[b]	1[b]	NA	1[b]
Conversion Factor	days/hour	NA	0.042	0.042	0.042	0.042	NA	NA
Dermal contact								
Skin area	m^2/event	NA	0.53[e]	0.815[f]	0.316[d]	0.53[e]	NA	0.53[e]
Adherence factor	mg/cm^2	NA	1[c]	1[c]	1[c]	1[c]	NA	1[c]
Exposure frequency	events/year	NA	90[b]	24[b]	28[b]	75[c]	NA	350[a]
Exposure duration	years	NA	30[b]	6[a]	25[b]	30[a]	NA	30[a]
Body weight	kg	NA	70[a]	15[a]	70[a]	70[a]	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	2190[a]	9125[a]	10950[a]	NA	10950[a]
Conversion Factor	(kg-cm^2)/(mg-m^2)	NA	0.01	0.01	0.01	0.01	NA	0.01
Inhalation of VOCs and dust								
Inhalation rate	m^3/day	NA	20[a]	20[a]	20[a]	20[a]	NA	20[a]
Exposure time	hours/day	NA	2[b]	1[b]	8[b]	1[b]	NA	NA

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Exposure frequency	days/year	NA	90[b]	24[b]	28[b]	75[c]	NA	350[a]
Exposure duration	years	NA	30[b]	6[a]	25[b]	30[a]	NA	30[a]
Body weight	kg	NA	70[a]	15[a]	70[a]	70[a]	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	2190[a]	9125[a]	10950[a]	NA	10950[a]
Conversion Factor	days/hour	NA	0.042	0.042	0.042	0.042	NA	NA
Surface Water								
Incidental ingestion while swimming/wading/showering								
Drinking water ingestion rate	L/day	NA	NA	NA	NA	NA	NA	2[a]
Incidental water ingestion rate	L/hour	NA	0.05[g]	0.05[g]	0.05[g]	0.05[g]	NA	NA
Exposure time	hours/day	NA	2[b]	1[b]	8[b]	1[b]	NA	NA
Exposure frequency	days/year	NA	90[b]	24[b]	28[b]	45[b]	NA	350[a]
Exposure duration	years	NA	30[b]	6[a]	25[b]	30[a]	NA	30[a]
Body weight	kg	NA	70[a]	15[a]	70[a]	70[a]	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	2190[a]	9125[a]	10950[a]	NA	10950[a]
Dermal contact while swimming/wading/showering								
Skin area	m^2	NA	0.53[e]	1.733[i]	0.53[e]	1.94[c]	NA	1.94[c]
Exposure time	hours/day	NA	2[b]	1[b]	8[b]	1[b]	NA	0.25[c]
Exposure frequency	days/year	NA	90[b]	24[b]	28[b]	45[b]	NA	350[a]
Exposure duration	years	NA	30[b]	6[a]	25[b]	30[a]	NA	30[a]
Body weight	kg	NA	70[a]	15[a]	70[a]	70[a]	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	2190[a]	9125[a]	10950[a]	NA	10950[a]
Conversion Factor	(m/cm)(L/m^3)	NA	10	10	10	10	NA	10
Inhalation of VOCs								
Inhalation rate	m^3/day	NA	20[a]	20[a]	20[a]	20[a]	NA	20[a]
Exposure time	hours/day	NA	2[b]	1[b]	8[b]	1[b]	NA	NA
Exposure frequency	days/year	NA	90[b]	24[b]	28[b]	45[b]	NA	350[a]
Exposure duration	years	NA	30[b]	6[a]	25[b]	30[a]	NA	30[a]
Body weight	kg	NA	70[a]	15[a]	70[a]	70[a]	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	25550[a]	25550[a]	25550[a]	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	2190[a]	9125[a]	10950[a]	NA	10950[a]
Conversion Factor	days/hour	NA	0.042	0.042	0.042	0.042	NA	NA
Volitilization factor	L/m^3	NA	0.5[a]	0.5[a]	0.5[a]	0.5[a]	NA	0.5[a]

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Groundwater								
Drinking water ingestion								
Drinking water ingestion rate	L/day	NA	NA	NA	1[a]	NA	NA	2[a]
Exposure frequency	days/year	NA	NA	NA	180[b]	NA	NA	350[a]
Exposure duration	years	NA	NA	NA	25[b]	NA	NA	30[a]
Body weight	kg	NA	NA	NA	70[a]	NA	NA	70[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	9125[a]	NA	NA	10950[a]
Dermal contact while showering								
Skin area	m^2	NA	NA	NA	1.94[h]	NA	NA	1.94[h]
Exposure time	hours/day	NA	NA	NA	0.25[c]	NA	NA	0.25[c]
Exposure frequency	days/year	NA	NA	NA	180[b]	NA	NA	350[a]
Exposure duration	years	NA	NA	NA	25[b]	NA	NA	30[a]
Body weight	kg	NA	NA	NA	70[a]	NA	NA	70[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	9125[a]	NA	NA	10950[a]
Conversion Factor	$(m/cm)(L/m^3)$	NA	NA	NA	10	NA	NA	10
Inhalation of VOCs during household water use								
Inhalation rate	m^3/day	NA	NA	NA	20[a]	NA	NA	20[a]
Exposure frequency	days/year	NA	NA	NA	180[b]	NA	NA	350[a]
Exposure duration	years	NA	NA	NA	25[b]	NA	NA	30[a]
Body weight	kg	NA	NA	NA	70[a]	NA	NA	70[a]
Carcinogen averaging time	days	NA	NA	NA	25550[a]	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	9125[a]	NA	NA	10950[a]
Volatilization factor	L/m^3	NA	NA	NA	0.5[a]	NA	NA	0.5[a]
Foodstuffs								
Ingestion of venison								
Conversion factor	unitless	NA	1.25	NA	NA	NA	NA	1.25
Browse ingestion rate	kg dry weight/day	NA	0.87[q]	NA	NA	NA	NA	0.87[b]
Fraction browse ingested from site	unitless	NA	0.46[q]	NA	NA	NA	NA	0.46[b]
Fat ratio (venison to beef)	unitless	NA	0.20	NA	NA	NA	NA	0.20
Venison ingestion rate	kg/day	NA	0.03[b]	NA	NA	NA	NA	0.03[b]
Fraction ingested	unitless	NA	1[b]	NA	NA	NA	NA	1[b]
Exposure frequency	days/year	NA	365[b]	NA	NA	NA	NA	365[b]
Exposure duration	years	NA	30[b]	NA	NA	NA	NA	30[a]

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Body weight	kg	NA	70[a]	NA	NA	NA	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	NA	NA	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	NA	NA	NA	NA	10950[a]
Ingestion of beef, pork								
Resuspension multiplier	unitless	NA	NA	NA	NA	NA	NA	0.25[j]
Quantity of pasture ingested	kg dry weight/day	NA	NA	NA	NA	NA	NA	7.2[k]
Fraction of year cow is on-site	unitless	NA	NA	NA	NA	NA	NA	1[b]
Fraction of cow's food from on-site	unitless	NA	NA	NA	NA	NA	NA	0.9[b]
Quantity of soil ingested by cow	kg/day	NA	NA	NA	NA	NA	NA	1[l]
Beef ingestion rate	kg/day	NA	NA	NA	NA	NA	NA	0.075[m]
Fraction ingested	unitless	NA	NA	NA	NA	NA	NA	1[b]
Exposure frequency	days/year	NA	NA	NA	NA	NA	NA	365[b]
Exposure duration	years	NA	NA	NA	NA	NA	NA	30[a]
Body weight	kg	NA	NA	NA	NA	NA	NA	70[a]
Carcinogen averaging time	days	NA	NA	NA	NA	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	NA	NA	NA	10950[a]
Ingestion of milk products								
Resuspension multiplier	unitless	NA	NA	NA	NA	NA	NA	0.25[j]
Quantity of pasture ingested	kg dry weight/day	NA	NA	NA	NA	NA	NA	16.1[k]
Fraction of year cow is on-site	unitless	NA	NA	NA	NA	NA	NA	1[b]
Fraction of cow's food from on-site	unitless	NA	NA	NA	NA	NA	NA	0.6[b]
Quantity of soil ingested by cow	kg/day	NA	NA	NA	NA	NA	NA	1[l]
Milk ingestion rate (Adult)	kg/day	NA	NA	NA	NA	NA	NA	0.305[m]
Milk ingestion rate (Child)	kg/day	NA	NA	NA	NA	NA	NA	0.509[n]
Fraction ingested	unitless	NA	NA	NA	NA	NA	NA	1[b]
Exposure frequency	days/year	NA	NA	NA	NA	NA	NA	365[b]
Exposure duration (Adult)	years	NA	NA	NA	NA	NA	NA	24[a]
Exposure duration (Child)	years	NA	NA	NA	NA	NA	NA	6[a]
Body weight (Adult)	kg	NA	NA	NA	NA	NA	NA	70[a]
Body weight (Child)	kg	NA	NA	NA	NA	NA	NA	15[a]
Carcinogen averaging time	days	NA	NA	NA	NA	NA	NA	25550[a]
Noncarcinogen averaging time (Adult)	days	NA	NA	NA	NA	NA	NA	8760[a]
Noncarcinogen averaging time (Child)	days	NA	NA	NA	NA	NA	NA	2190[a]
Ingestion of vegetables								
Resuspension multiplier	unitless	NA	NA	NA	NA	NA	NA	0.26[o]
Vegetable ingestion rate	kg/day	NA	NA	NA	NA	NA	NA	0.2[m]

Table 6-2. Parameters Used to Quantify Exposures for Each Medium and Receptor (continued)

Parameter	Units	Security Guard/ Maintenance Worker (1)	Hunter/ Trapper (2)	Child Trespasser (3)	National Guard Trainee (4)	Open Recreator (5)	Open Industrial Worker (6)	Resident Farmer (child/adult) (7)
Fraction ingested	unitless	NA	NA	NA	NA	NA	NA	0.4[m]
Exposure frequency	days/year	NA	NA	NA	NA	NA	NA	365[b]
Exposure duration	years	NA	NA	NA	NA	NA	NA	30[a]
Body weight	kg	NA	NA	NA	NA	NA	NA	70[a]
Carcinogen averaging time	days	NA	NA	NA	NA	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	NA	NA	NA	NA	NA	10950[a]
Ingestion of fish								
Fish ingestion rate	kg/day	NA	0.054[p]	NA	NA	NA	NA	0.054[p]
Fraction ingested	unitless	NA	1[b]	NA	NA	NA	NA	1[b]
Exposure frequency	days/year	NA	365[b]	NA	NA	NA	NA	365[b]
Exposure duration	years	NA	30[b]	NA	NA	NA	NA	30[a]
Body weight	kg	NA	70[a]	NA	NA	NA	NA	70[a]
Carcinogen averaging time	days	NA	25550[a]	NA	NA	NA	NA	25550[a]
Noncarcinogen averaging time	days	NA	10950[a]	NA	NA	NA	NA	10950[a]

NA = not applicable for this scenario.
[a] RAGS, Part B (EPA 1991c).
[b] Site-specific (value assumed for site or value obtained from site personnel).
[c] Risk Dermal Guidance (EPA 1992a).
[d] 50th percentile surface area for head, hands, forearms, for male adult (EPA 1992b).
[e] Average surface area for head, hands, forearms and lower legs for an adult (EPA 1992b).
[f] Average surface area for head, hands, forearms, torso, and lower legs for a child (EPA 1992b).
[g] RAGS, Part A (EPA 1989c).
[h] Average total body surface area for an adult (EPA 1992b).
[i] Average total body surface area for a child (EPA 1992b).
[j] Plant mass loading factor for pasture (Hinton 1992).
[k] International Atomic Energy agency 1994.
[l] Soil ingestion by dairy cattle (Darwin 1990).
[m] Exposure Factors Handbook (EPA 1989d).
[n] Pao, et al., 1982.
[o] Plant mass loading factor for vegetables (Pinder 1989).
[p] Standard default Exposure Factors (EPA 1991b).
[q] Sample et al. 1996 and Mautz et al. 1976.

Table 6-3. Modified Caretaker – Managed Recreational Receptors and Activities

Receptor	Typical Activities
Authorized Uses	
Security guard – maintenance worker	Security patrol, remediation
Hunters and trappers	Deer hunting, trapping, fishing
Nature study participants	University studies, bird watching
Unauthorized Uses	
National Guard personnel outside of authorized areas	National Guard trainee trespassing
Trespassers	Children playing and swimming, unauthorized hunting

Fishing is currently prohibited; however, fishing has occurred in the past and trespassers may fish the viable ponds.

Based on the available information, it is assumed that the hunter/trapper may be the same individual, and could be exposed to surface soils, sediments, and surface water over a three-month period and has a steady diet of venison and fish. See **Table 6-2** for parameter values used to evaluate exposures to the hunter/trapper in this BHHRA.

Nature Study Participant

Research projects associated with nearby Youngstown State University take place at RVAAP. Projects include: a migratory bird study that takes place on a 10-ha (25-acre) forest plot outside of WBG; foodchain studies; a salamander study; a bat study; archeological studies; and bird tours. All studies take place outside of AOCs. The frequency that study participants come to the site varies but is generally less than 3 to 4 times/week for several months, as opposed to years. Because these receptors are generally short-term visitors to the facility and would likely result in minimal risks/hazards from acute or long-term exposures at WBG, they will not be addressed quantitatively in this risk assessment.

6.3.2.2 National Guard – Managed Recreational

Three receptor categories have been identified under the National Guard – Managed Recreational scenario. One of the assumptions for this scenario is that as part of acquiring the RVAAP lands, the OHARNG will take on the forestry and land management responsibilities at the facility. Therefore, two of the receptors for this scenario are the same receptors identified for the "Modified Caretaker – Managed Recreational" land use: the "hunter/trapper" and the "nature study" receptor.

Unique to this land use designation is the National Guard receptor. Information describing this receptor has been obtained from two primary sources: the Range and Training Land Program Development Plan, issued in draft form by the OHARNG in late 1998, and a July 1998 interview with Lt. Col. Tom Tadsen, officer in charge of the RTLS for the OHARNG. The Development Plan reviewed available training capacity and compared it to long-term training needs. In the process, it described the types of training that could potentially take place at RVAAP (**Table 6-4**).

Table 6-4. National Guard Training Activities

Training Type	Currently Available	Needed
Maneuver Training Areas		
Light Maneuver Area	X	
Other		
Tracked Vehicle Drivers Course	X	
Personnel and Equipment Drop Zone	X	
Convoy Training Route	X	
Tracked Vehicle Driver's Training Course	X	
Land Navigation Course	X	
Hand Grenade Qualification Course		X
Hand Grenade Familiarization Range		X
Military Operations in Urban Terrain (MOUT)		X

In general, National Guard units participate in weekend training at RTLS, with some 2-week training. Weekend training that currently takes place at the RTLS is summarized below:

- day/night wheeled vehicle convoys, involving drives on paved road, including staged ambushes;
- night blackout drives;
- self-propelled artillery driver training for armored vehicles, involving great dust generation;
- command-post exercises, including setting up tactical operations and sleeping on the ground;
- armored vehicle recovery, involving recovery of vehicles from a prepared site;
- dismounted road march, on-foot marches on paved and unpaved areas, including stream crossings;
- Bailey Bridge assembly, launching, and disassembly over and adjacent to streams;
- defense of a fixed position, requiring fox holes up to 5 feet deep.

An example of week-long training is "early warning team" training, involving all-week tracking of aircraft and artillery from tent positions.

According to RTLS staff (pers. comm. Lt. Col. Tadsen, July 7, 1998), the most likely training uses of WBG should it become available could include such activities as tank staging, involving overnight tank parking and maintenance, or personnel and equipment insertions from helicopters, including medical rescue hoists.

The number of trainees at the RTLS and the number of weekends the facility is in use continues to increase. This will increase even more as more lands are developed for training. In 1997 there were an estimated 21,000 training man-days at the facility. This is expected to increase to 24,000 to 27,000 man-days by 1999. According to the Development Plan, the typical training year includes weekends, less holiday weekends, and annual training, which for the RTLS is 173 days/year.

In general, individual trainees visit the facility only one to two times per year. The maximum amount of time a trainee is expected to be at the facility in a year is 2 weeks. However, OHARNG personnel are stationed at the RTLS administration area full-time. These personnel are responsible for managing training activities and schedules and insuring units are in compliance with facility requirements. This involves checking on units during their activities. It is assumed that, at worst case, an individual stationed at RTLS could visit a training area approximately 180 days/year.

According to RTLS staff (pers. comm. Lt. Col. Tadsen, July 7, 1998), all potable water will come from municipal water supply. There are no plans to obtain water from groundwater wells. However, based on the possibility that this decision could be reversed in the future, this BHHRA will evaluate the exposure of the National Guard receptor to groundwater use.

Parameter values used in this BHHRA to evaluate the National Guard receptors are found in **Table 6-2**.

6.3.2.3 Open Recreational

This potential land use scenario has been developed to provide information on potential future risk should the RVAAP revert to a recreational-type use. Various potential recreational uses are possible, including a state or federal recreational area, a wildlife sanctuary, a park, ballfields, etc. Because this use is not defined clearly, the exposure pathway analysis involves a reasonable worst-case assessment of recreational receptor activities. It is assumed that the recreator could be exposed to surface soils, stream sediments, and surface water. No groundwater use is assumed for this land use. Pathways and parameters used to define this scenario are listed in **Table 6-2**.

6.3.2.4 Open Industrial

Like the open recreational scenario, the exposure assessment for this land use is designed to cover the reasonable worst-case receptor-activity patterns that could occur under a future commercial/industrial land use. Under this land use it is assumed that excavation, fill, and construction work (activities such as the rare occasion of digging a foundation for a post or bridge) could take place; therefore, receptors could be exposed to what is now considered subsurface soils. Based on discussions with site personnel, the activities associated with a construction worker scenario are covered within the open industrial land use. Therefore, the open industrial land use is evaluated instead of the construction worker scenario. Most of the parameter values for this open industrial land use, listed in **Table 6-2**, are taken from standard CERCLA industrial exposure assumptions (EPA 1991c).

6.3.2.5 Open Residential

This land use scenario represents the true baseline assessment against which all decisions, including decisions to maintain institutional controls, can be made. It represents the worst-case exposures of all land use/receptor combinations. The adult resident farmer is assumed to be exposed chronically to all media, including groundwater and foodstuffs. The child resident farmer (using standard default values from EPA 1991c, such as an exposure duration of 6 years) is also evaluated for the ingestion of soil/sediment and ingestion of milk, since the child ingestion rates are higher than adult ingestion rates for these pathways. It is assumed that the farmer lives on the WBG land, raises livestock and vegetables, hunts and digs into subsurface soils (see **Figure 6-2**). Parameters used to represent activities patterns are listed in **Table 6-2** and generally come from standard default values defined by the EPA (1991c).

6.3.3 Quantification of Intake

Intake or dose is defined as the amount of contaminant that could be in contact with the body (e.g., skin, lungs, etc.) per unit body weight per unit time. For the WBG BHHRA, the intakes and doses for each receptor were quantified using methods presented in the *SAP Addendum for the Phase II Remedial Investigation at WBG and Determination of Facility-Wide Background at RVAAP* (USACE 1998a). The equations used to estimate intake are presented in the following subsections for soils and sediments, groundwater and surface water, and ingestion of foodstuffs. **Table 6-2** provides the parameters used to estimate exposure. Parameter values were selected based on EPA guidance and from input from the OHARNG and RVAAP facility staff.

6.3.3.1 Soils and Sediments Exposure Pathways

Incidental ingestion of soils and sediments was estimated for chemicals using Eq. 1:

$$Chemical\ Intake\ (mg / kg - day) = \frac{C_s \times IR_s \times EF \times ED \times FI \times ET \times CF}{BW \times AT} \quad \textbf{(1)}$$

where:

C_s = chemical concentration in soils or sediments (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 adjustment (hr/day),
CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or noncarcinogens.

The dermally absorbed dose (DAD) from chemicals in soils and sediments was calculated by using Eq. 2.

$$Chemical\ DAD\ (mg / kg - day) = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}\ , \quad \textbf{(2)}$$

where:

C_s = chemical concentration in soils or sediments (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 (1 mg/cm^2),
ABS = chemical-specific absorption factor (0.1% for inorganics and 1.0% for organics),
EF = exposure frequency (events/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or noncarcinogens.

Inhalation of soils or dry sediments was calculated using Eq. 3:

$$Chemical\ Intake\ (mg / kg - day) = \frac{C_s \times IR_a \times EF \times ED \times (VF^{-1} + PEF^{-1}) \times ET \times CF}{BW \times AT}\ , \quad \textbf{(3)}$$

where:

C_s = chemical concentration in soils or sediments (mg/kg),
IR_a = inhalation rate (m^3/day),
EF = exposure frequency (days/year),
ED = exposure duration (years),
VF = volatilization factor (chemical-specific m^3/kg),
PEF = particulate emission factor (9.24×10^8 m^3/kg),
ET = exposure time adjustment (hr/day)

CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or non-carcinogens.

6.3.3.2 Groundwater and Surface Water Exposure Pathways

Drinking water ingestion was estimated using Eq. 4:

$$Chemical\ Intake\,(mg/kg\text{ - }day) = \frac{C_w \times IR_w \times EF \times ED}{BW \times AT}, \quad \textbf{(4)}$$

where:

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

Incidental ingestion of surface water while swimming was using Eq. 5:

$$Chemical\ Intake\,(mg/kg\text{ - }day) = \frac{C_w \times IR_w \times ET \times EF \times ED}{BW \times AT}, \quad \textbf{(5)}$$

where:

C_w = chemical concentration in water (mg/L),
IR_w = ingestion rate (L/hr),
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 noncarcinogens.

The dermally absorbed dose from dermal contact with chemicals in surface water or groundwater was calculated by using Eq. 6:

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

where:

C_w = chemical concentration in water (mg/L),
CF = conversion factor [(m/100 cm) × (1000 L/m^3)],
PC = permeability constant (chemical-specific cm/hr),
SA = skin surface area exposed to soil (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 and noncarcinogens.

Inhalation of VOCs from surface water or groundwater was estimated by Eq. 7:

$$Chemical\ Intake\ (mg/kg\text{ - }day) = \frac{C_w \times IR_w \times K \times EF \times ED \times ET \times CF}{BW \times AT}, \quad \textbf{(7)}$$

where:

C_w = chemical concentration in water (mg/L),
IR_w = inhalation rate (m^3/day),
K = volatilization factor (0.0005 × 1000 L/m^3),
EF = exposure frequency (days/year),
ED = exposure duration (years),
ET = exposure time adjustment (hr/day),
CF = conversion factor for ET (day/hr),
BW = body weight (kg),
AT = averaging time (days) for carcinogens or noncarcinogens.

6.3.3.3 Ingestion of Foodstuffs

Ingestion of chemicals from the consumption of foodstuffs was estimated by using Eq. 8. Supplemental equations for calculating the concentration of chemical in the food source are presented in *SAP Addendum for the Phase II Remedial Investigation at WBG and Determination of Facility-Wide Background at RVAAP* (USACE 1998a).

$$Chemical\ Intake\ (mg/kg\text{ - }day) = \frac{C_f \times IR_f \times EF \times ED}{BW \times AT}, \quad \textbf{(8)}$$

where:

C_f = chemical concentration in food (mg/kg),
IR_f = ingestion rate of food (kg/day),
EF = exposure frequency (day/year),
ED = exposure duration (years),
BW = body weight (kg),
AT = averaging time (days) for carcinogens and noncarcinogens.

6.3.4 Exposure Point Concentrations

To calculate exposure for each receptor, an exposure point concentration (EPC) in each medium must be estimated. The EPC represents the chemical concentration a receptor is likely to come in contact with over the duration of exposure. Receptors may be exposed to chemicals by direct pathways (e.g., contact with media at a specific source area) or indirect pathways (e.g., with other media contaminated by chemicals that migrated away from the specific source). Exposure from direct contact pathways represents exposure to media at the source, and the EPC is based on data collected at the source. Indirect contact pathways represent exposure to secondary media (groundwater, surface water, sediments, air, and biota) that have been contaminated by chemicals that have migrated from the source or by bio-uptake into plants and animals. Based on the results of

the Phase I Investigation, no major chemical migration modeling was deemed necessary for the BHHRA since chemical concentrations in media away from the source were generally nondetect [chemical migration modeling may be considered for future studies at this AOC (e.g., for a feasibility study)]. For this BHHRA, sampling results from Phase I and Phase II were used to represent both source and secondary media exposure point concentrations. Current measured concentrations of chemicals were used to represent future concentrations in the medium or media of interest.

Two types of risk estimates are being generated for the WBG BHHRA. The first type of risk evaluation considers the entire WBG as the area for a single exposure unit aggregate, in an attempt to identify a more reasonable area over which a receptor may be exposed. This type of risk evaluation also provides representative contaminant concentrations over an area where the receptor may roam. For this first type of risk evaluation, the EPCs developed for each COPC represent an UCL_{95} on the mean or the maximum detected value for all locations within the aggregate, whichever is smaller. The second type of risk evaluation focuses on risks that are estimated at individual sampling points, to evaluate the spatial distribution of risks across the entire site. The results of this location-by-location risk evaluation are intended to support the results of the aggregate risk evaluation, by evaluating the locations that contribute significantly to the aggregated risks. For this location-by-location risk evaluation, the maximum detected concentration is used as the exposure point concentration. This method allows for the identification of risk "hot spots."

EPCs are calculated using EPA guidance, *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA 1992b). The data are tested using the Shapiro-Wilk test to determine distribution, normal or lognormal, of the concentrations. The UCL_{95} on the mean is calculated using the normal distribution equation (see Eq. 9) when the concentrations are normally distributed, when concentrations are not judged to be normally or lognormally distributed, when the dataset contains fewer than 5 detections, or when the frequency of detection is less than 50 percent. For these situations, the UCL_{95} on the mean is calculated using the following equation:

$$UCL_{95}(normal) = \overline{x_n} + \frac{(t)(s_x)}{\sqrt{n}}, \qquad \textbf{(9)}$$

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.

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

$$UCL_{95}(lognormal) = e\left(\overline{x_l} + 0.5(s_l^2) + \frac{(S_l)(H)}{\sqrt{n-1}}\right), \qquad \textbf{(10)}$$

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.

6.3.5 Intake Results

Results of the exposure assessment are combined with information presented in Section 6.4 (Toxicity Assessment) in order to calculate risks and hazards for each receptor. These risks are presented in Section 6.5 (Risk Characterization) and in Appendix J.

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 the EPA. This section provides the results of the EPA evaluation of the RVAAP/WBG COPCs.

6.4.1 Toxicity Information and EPA Guidance for Noncarcinogens

Noncarcinogenic effects are evaluated by comparing an exposure or dose with a reference dose (RfD) or reference air concentration (RfC). The RfD is determined using available dose-response data for individual chemicals. Scientists determine the dose below which no adverse effects are seen and add a safety factor (10 to 1000) to determine the RfD or RfC. RfDs are identified by scientific committees supported by EPA. The RfDs available for the COPCs present in the RVAAP/WBG media are listed in **Table J.4.1** (EPA 1996d, 1997b, 1998a). In this BHHRA, RfCs, measured in milligrams per cubic meter, were converted to RfDs measured in units of milligrams per kilogram per day, by using the inhalation rate and body weight of an adult [i.e., RfC $\times$ 20 m^3/d $\times$ (1/70 kg) = RfD)] (EPA 1996b).

Chronic RfDs are developed for protection from long-term exposure to a chemical (7 years to a lifetime); subchronic RfDs are used to evaluate short-term exposure (2 weeks to 7 years) (EPA 1989c). Since the potential receptors at WBG are not considered to have "short-term" exposures, a conservative approach has been taken for this BHHRA by using only chronic RfDs [chronic RfDs generally result in hazard quotients that are at least as large as (sometimes larger than) hazard quotients calculated from subchronic RfDs].

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

6.4.2 Toxicity Information and EPA 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 cancer risk, which is cancer incurred in addition to normally expected rates of cancer development.

EPA's Integrated Risk Information System (IRIS) (EPA 1998a) expresses inhalation cancer potency as a unit risk based on concentration, or risk per ug of chemical per m^3 of ambient air. Because cancer risk characterization requires a potency expressed as a risk per mg/kg-day, the unit risk must be converted to the mathematical equivalent of an inhalation cancer slope factor, or risk per unit dose. Because the inhalation unit risk is based on continuous lifetime exposure of an adult human (assumed to inhale 20 m^3 of air per day and to weigh 70 kg), the mathematical conversion from inhalation unit risk to inhalation cancer slope factor has been performed by multiplying the unit risk (risk per ug/m^3) by 70 kg and by 1,000 ug/mg, and dividing the result by 20 m^3/day.

Slope factors used in the evaluation of risk from exposure to carcinogenic RVAAP/WBG COPCs are listed in **Table J.4.2** (EPA 1996d, 1997b, 1998a).

6.4.3 Estimation of Toxicity Values for Dermal Exposure

Oral RfDs and slope factors were adjusted for the evaluation of the dermal exposure pathway (EPA 1989c, 1996c). Most RfDs and slope factors are expressed as the amount of substance administered per time and body weight; however, dermal exposure to chemicals in soil and water is expressed as absorbed dose.

For the dermal assessments in this BHHRA, the oral RfD and/or oral slope factor for each COPC is adjusted by the percent gastrointestinal absorption efficiency (%GI) for that chemical. The measured %GIs are available for only a limited number of chemicals; for those chemicals for which no %GI is available in the literature, 80 percent was used for VOCs, 50 percent for SVOCs, and 20 percent for inorganics (EPA 1996d). Wide ranges of %GI values can be found for some chemicals and, in the absence of chemical-specific absorption data, the values are often estimated from data for related chemical structures; most organic compounds are readily absorbed (i.e., %GI=100).

Adjustments, which favor conservatism, are made to the oral RfDs and slope factors used in the dermal assessments. The oral RfD is multiplied by the %GI/100, and the slope factor is divided by the %GI/100 to give the absorbed dose RfD and absorbed dose slope factor, respectively. These toxicity values (listed in **Tables J.4.1** and **J.4.2**) are then used to evaluate the risk to human health from dermal exposure to the RVAAP/WBG COPCs.

6.4.4 Toxicity Values Used in the BHHRA

Section 6.8 (Toxicity Profiles) provides general as well as chemical-specific information about health effects related to the COPCs identified in this BHHRA. Both carcinogenic and noncarcinogenic health effects are considered. Toxicity profiles are also provided for a selection of RVAAP/WBG COPCs that can be evaluated only qualitatively because of the absence of toxicity values.

The toxicity information is derived from human and laboratory animal research and from occupational studies. Much of the information pertaining to specific contaminants is taken from EPA's IRIS (EPA 1998a) and Health Effects Assessment Summary Table (HEAST) (EPA 1994a). A database of summarized toxicity values, maintained by the Life Sciences Division of Oak Ridge National Laboratory, has been accessed for use in this BHHRA (see the World Wide Web site http://risk.lsd.ornl.gov/tox/tox_values.html). This database provides toxicity profiles and toxicity values, using a hierarchy of IRIS, HEAST, National Center for Environmental Assessment (NCEA), and other EPA-affiliated sources. References for each toxicity profile are listed in Section 10.0. **Tables J.4.1** and **J.4.2** summarize the toxicity information for those RVAAP/WBG COPCs for which quantitative information (i.e., slope factors and RfDs) is available.

6.4.5 Toxicity Assumptions

Assumptions made about toxicity for COPCs are:

- Total chromium as a metal is evaluated conservatively with the toxicity of hexavalent chromium. This is a conservative assumption since Chromium VI is not identified as an SRC. Also, the fact that hexavalent chromium is more toxic than trivalent chromium and is a less commonly occurring form of the metal adds to this conservative assumption.

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

- Toxicity Equivalency Factors (TEFs) are applied to carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs) (EPA 1996d). The following TEFs are used to convert the following cPAHs (which are identified as COPCs) to an equivalent concentration of benzo(*a*)pyrene.

cPAH	TEF
Benzo(*a*)pyrene	1
Benzo(*a*)anthracene	0.1
Benzo(*b*)fluoranthene	0.1
Dibenzo(*a,h*)anthracene	1
Indeno(1,2,3-*c,d*)pyrene	0.1

6.4.6 Chemicals without EPA Toxicity Values

No slope factors and RfDs are available for some detected chemicals at RVAAP/WBG because the carcinogenic and/or noncarcinogenic effects of those chemicals have not yet been determined. Although these chemicals may contribute to carcinogenic and noncarcinogenic effects from exposure to the contaminated RVAAP/WBG media, their effects cannot be quantified at the present time. In addition, epidemiological studies have indicated that several chemicals are not carcinogenic; consequently, these species do not have slope factors. A qualitative summary of toxicity information for some RVAAP/WBG COPCs without toxicity values is presented in Section 6.8 (Toxicity Profiles). Also, previously withdrawn or provisional toxicity values are used for the following RVAAP/WBG COPCs: arsenic (a withdrawn inhalation slope factor is used) and benzo(*a*)pyrene (a provisional inhalation slope factor is used). Without these withdrawn or provisional values, the inhalation pathway could not be evaluated for these chemicals. By using these withdrawn/provisional values, these two COPCs are evaluated quantitatively in this BHHRA.

6.4.7 Qualitative COPC Evaluation

Those COPCs identified as qualitative COPCs can be found in **Tables J.2.1** through **J.2.5** (for each medium). Available toxicity profiles for these chemicals are presented in Section 6.8 (Toxicity Profiles).

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 exposure) and chemical-specific dose-response data (i.e., slope factors) to estimate the probability that an individual will develop cancer over a lifetime. Potential noncarcinogenic effects are characterized by comparing projected intakes of contaminants to toxicity values (i.e., RfDs or RfCs). The numerical risk and HQ 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 (Section 6.6).

The chapter is divided into three Sections; the methodology is presented in Section 6.5.1, while the results are presented in Section 6.5.2. Remedial Goal Options (RGOs) are presented for chemicals of concern in Section 6.5.3.

6.5.1 Methodology

Risk characterization integrates the findings of the exposure assessment to estimate the likelihood that receptors experience adverse effects as a result of exposure to COPCs (EPA 1989c). Risks are calculated from

toxicity information and the results of the exposure assessment. For carcinogens, incremental lifetime cancer risks (ILCRs), or the increased lifetime probability of cancer, are calculated. This ILCR represents the increased chance above the background of contracting cancer. In the United States, the background chance is about 3 in 10, or 3×10^{-1} (American Cancer Society 1990). The resulting ILCRs are compared to the range specified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) of 10^{-6} to 10^{-4}, or 1 in 1 million to 1 in 10,000 persons developing cancer (EPA 1990b). ILCRs below 10^{-6} are considered acceptable risks. ILCRs above 10^{-4} are considered unacceptable risks. The range between 10^{-6} and 10^{-4} is a gray area 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 risk of developing cancer is determined by applying Eq. 11 (EPA 1989c):

$$ILCR = I \times CSF \quad , \tag{11}$$

where:

I = chronic daily intake or dermally absorbed dose from exposure assessment (mg/kg-day),
CSF = cancer slope factor $(mg/kg\text{-}day)^{-1}$.

For a given pathway, with simultaneous exposure of a receptor to several carcinogens, the total risk to a receptor is the sum of the ILCRs for each carcinogen encountered in all sources and each pathway. Equation 12 is used to calculate the total ILCR:

$$ILCR_{total} = \Sigma\, ILCR_i \quad , \tag{12}$$

where:

$ILCR_{total}$ = total chance of cancer incidence,
$ILCR_i$ = ILCR for the i^{th} contaminant.

In addition to developing cancer from exposure to contaminants, an individual may experience toxic effects from exposures to hazardous substances. The term toxic effects describes 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 chemicals are evaluated by comparing an exposure level or intake to an RfD. The RfD is the threshold level below which no toxic effects are expected to occur in a normal population, including sensitive subpopulations. The ratio of intake over the RfD is the HQ (EPA 1989c) and is defined as:

$$HQ = \frac{I}{RfD} \quad , \tag{13}$$

where:

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

The HQs for each contaminant are summed to obtain a hazard index (HI). An HI greater than 1 has been defined as the level of concern for potential adverse noncarcinogenic health effects (EPA 1989c). 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 the simultaneous exposure of a receptor to several chemicals, an HI is calculated as the sum of the individual HQs for all noncarcinogens encountered in all sources for each pathway:

$$HI = \sum HQ_i \quad , \tag{14}$$

where:

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

The COCs for a given medium are defined as those contaminants that have total cancer risks $\geq 10^{-6}$ and/or HIs $\geq$ 1.0 within a land use scenario and that are not eliminated during the uncertainty analysis.

6.5.2 Risk Characterization Results

The risks for the WBG site are evaluated by exposure unit aggregate (i.e., AOC-wide) and by sample location. The results from these two types of risk evaluations are presented in Sections 6.5.2.1 and 6.5.2.2.

The exposure unit aggregate risks are performed to evaluate a reasonable risk exposure across the entire AOC. These results have addressed the reasonable maximum exposure (RME) concept developed by EPA. 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 exposure point concentration implies that a receptor may come into contact with contaminants throughout the AOC. The results in Section 6.5.2.1, presented by medium, is considered to be the baseline risk results for the WBG. The determination of COCs and the development of RGOs are based on the results from the aggregated data. That is, the COCs for the BHHRA are selected from the results of the exposure aggregate risk evaluation and RGOs are calculated for these COCs.

The results of sampling location risk estimates are used to support the results of the aggregate risks, as well as to evaluate the spatial distribution of risks across the entire site. The sampling location risk estimates are used to spatially define source areas of elevated risks for the COCs that have been identified in the aggregate risk evaluation. Section 6.5.2.2 presents the results of the location-by-location risks. These results are also presented graphically in Appendix J (see **Figures J.1** to **J.23**). Since the assumption that a receptor remains in one location over the entire exposure duration is unreasonable, this location-by-location evaluation is useful for focusing on the highest risk locations within the AOC. For this reason, the location-by-location risk/hazard results are only presented graphically (Appendix J) and should be used primarily to help locate priority areas within the AOC, not as the determining factor in the decision to implement a remedial action. Consequently, only those locations that produce risk estimates in the "large risk/hazard" category have been listed in Section 6.5.2.2.

6.5.2.1 Results of the Aggregated Risks

Risks are characterized for the exposure unit aggregates (i.e., across the entire WBG site) for each medium/land use/receptor combination. COCs are identified if total risks for a chemical exceed 10^{-6} or total HIs exceed 1.0 for each land use/receptor combination. General observations of the aggregate risk evaluations are presented in Sections 6.5.2.1.1 to 6.5.2.1.6 for each medium evaluated in this BHHRA. Section 6.5.2.1.7 summarizes the COCs resulting from the aggregate risk evaluation, summarizing those COCs that account for the majority of the overall risk or hazard.

6.5.2.1.1 Groundwater aggregate

Table 6-5 presents the risks and hazards for the two receptors (National Guard and on-site resident farmer) that have been evaluated for groundwater.

Table 6-5. Groundwater Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/L)	95% UCL on Mean (mg/L)	Exposure Point Conc. (mg/L)	Statistic for EPC	Dermal HQ	Ingestion HQ	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Analyte[a]
LAND USE/RECEPTOR: National Guard-Managed Recreational/National Guard														
Manganese	8/9	2.92E+00	2.96E+01	2.92E+00	Max Detect	5.4E-02	4.5E-01		5.0E-01					
Inorganics Pathway Total						5.4E-02	4.5E-01		5.0E-01					
Bis(2-ethylhexyl)phthalate	1/8	4.50E-03	5.06E-03	4.50E-03	Max Detect	9.3E-04	1.6E-03		2.5E-03	9.3E-08	1.6E-07		2.5E-07	
Chloroform	3/9	1.70E-03	2.50E-03	1.70E-03	Max Detect	2.6E-04	1.2E-03		1.5E-03	5.6E-09	2.6E-08	3.5E-06	3.5E-06	R
RDX	2/9	3.20E-02	1.04E-02	1.04E-02	UCL95	2.3E-03	2.4E-02		2.7E-02	2.7E-07	2.9E-06		3.1E-06	R
Organics Pathway Total						3.4E-03	2.7E-02		3.1E-02	3.6E-07	3.1E-06	3.5E-06	6.9E-06	R
Pathway Total - Chemicals						5.8E-02	4.7E-01		5.3E-01	3.6E-07	3.1E-06	3.5E-06	6.9E-06	R
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer														
Manganese	8/9	2.92E+00	2.96E+01	2.92E+00	Max Detect	1.1E-01	1.7E+00		1.8E+00					H
Inorganics Pathway Total						1.1E-01	1.7E+00		1.8E+00					H
Bis(2-ethylhexyl)phthalate	1/8	4.50E-03	5.06E-03	4.50E-03	Max Detect	1.8E-03	6.2E-03		8.0E-03	2.2E-07	7.4E-07		9.6E-07	
Chloroform	3/9	1.70E-03	2.50E-03	1.70E-03	Max Detect	5.0E-04	4.7E-03		5.2E-03	1.3E-08	1.2E-07	8.1E-06	8.2E-06	R
RDX	2/9	3.20E-02	1.04E-02	1.04E-02	UCL95	4.4E-03	9.5E-02		9.9E-02	6.2E-07	1.3E-05		1.4E-05	R
Organics Pathway Total						6.7E-03	1.1E-01		1.1E-01	8.5E-07	1.4E-05	8.1E-06	2.3E-05	R
Pathway Total - Chemicals						1.1E-01	1.8E+00		2.0E+00	8.5E-07	1.4E-05	8.1E-06	2.3E-05	R,H

[a]Chemical of concern codes: H = Hazard; R = Risk

For the National Guard's potential future exposure to groundwater (recall from Section 6.3.2.2 that this receptor is currently not exposed to groundwater, but is evaluated in this BHHRA for potential future exposure), chloroform and RDX are identified as COCs. Chloroform's risk of 3.5E-06 comes predominantly from the inhalation pathway, while the total risk for RDX (3.1E-06) comes mostly from the ingestion of drinking water. Across all COPCs, the total risk (6.9E-06) comes predominantly from the ingestion and inhalation pathways (total pathway risks of 3.1E-06 and 3.5E-06, respectively).

The evaluation of the on-site resident farmer reveals that chloroform (total risk of 8.2E-06) and RDX (total risk of 1.4E-05) are carcinogenic COCs, while manganese (HI of 1.8) is identified as the only noncarcinogenic COC. The HI for manganese is predominantly from the ingestion of drinking water. No other COCs are identified for groundwater. Further analysis reveals that only one of the nine manganese concentrations is above the manganese background level of 1020 µg/L. This one concentration (3070 µg/L) is used as the exposure point concentration for hazard calculations for groundwater (refer to **Table J.2.1** for groundwater summary statistics and screening results). Total risk across all COPCs is 2.3E-05, and total HI is 2.0.

6.5.2.1.2 Surface water aggregate

Since there are no surface water COPCs (see **Table J.2.2** for surface water summary statistics and screening results), there are no calculations of risks/hazards and consequently, no COCs are identified for surface water.

6.5.2.1.3 Sediment aggregate

Table 6-6 presents the risks and hazards for the five receptors that have been evaluated for sediment. Two of these receptors (the child trespasser and the hunter/trapper) are evaluated for two different land uses (the Maintained Industrial/Managed Recreational and the National Guard/ Managed Recreational land uses). Other receptors evaluated for exposure to sediment include the National Guard, the recreator, and the on-site resident farmer.

No sediment COCs are identified for the child/trespasser, the hunter/trapper, the National Guard, or the recreator receptors. As seen from **Table 6-6**, the total risk across all pathways and all chemicals for the hunter/trapper is 1.0E-06. However, since the largest total risk for an individual chemical is 7.7E-07 (i.e., < 1.0E-06), no sediment COCs are identified for this receptor.

Three carcinogenic COCs are identified for the on-side resident farmer exposed to sediment: benzo(*a*)anthracene (total risk of 1.1E-06), benzo(*a*)pyrene (total risk of 7.3E-06), and benzo(*b*)fluoranthene (total risk of 1.1E-06). For all three COCs, the total risk comes mostly from ingestion and dermal contact. The total risk across all COPCs is 9.8E-06, coming mostly from dermal contact (3.8E-06) and ingestion (5.9E-06).

6.5.2.1.4 Surface soil aggregate, direct contact

Table 6-7 presents the risks and hazards for the seven receptors that have been evaluated for direct contact with surface soil. Two of these receptors (the child trespasser and the hunter/trapper) are evaluated for two different land uses (the Maintained Industrial/Managed Recreational and the National Guard/Managed Recreational land uses). Other receptors evaluated for direct exposure to surface soil include the security guard/maintenance worker, the National Guard, the industrial worker, the recreator, and the on-site resident farmer.

Table 6-6. Sediment Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern Child/Ing.[a]	Chemical of Concern for Analyte[a]
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Child Trespasser																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	1.5E-03	1.0E-04			5.6E-06	1.6E-03						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	8.9E-03	1.8E-04			2.1E-06	9.1E-03			2.1E-10	2.1E-10		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	1.3E-02	6.5E-04				1.3E-02						
Inorganics Pathway Total						2.3E-02	9.4E-04			7.6E-06	2.4E-02			2.1E-10	2.1E-10		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.0E-08	1.3E-09	5.9E-14	4.2E-08		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							2.8E-07	8.9E-09	4.1E-13	2.9E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.0E-08	1.3E-09	5.9E-14	4.2E-08		
Indeno(1,2,3-cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							1.2E-08	3.9E-10	1.8E-14	1.3E-08		
Organics Pathway Total												3.7E-07	1.2E-08	5.5E-13	3.9E-07		
Pathway Total - Chemicals						2.3E-02	9.4E-04			7.6E-06	2.4E-02	3.7E-07	1.2E-08	2.1E-10	3.9E-07		
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter-Trapper																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	7.7E-04	8.4E-05			9.0E-06	8.6E-04						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	4.6E-03	1.5E-04			3.3E-06	4.8E-03			1.7E-09	1.7E-09		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	6.6E-03	5.2E-04				7.2E-03						
Inorganics Pathway Total						1.2E-02	7.5E-04			1.2E-05	1.3E-02			1.7E-09	1.7E-09		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.1E-07	5.1E-09	4.7E-13	1.1E-07		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							7.3E-07	3.6E-08	3.3E-12	7.7E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.1E-07	5.1E-09	4.7E-13	1.1E-07		
Indeno(1,2,3- cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							3.2E-08	1.6E-09	1.4E-13	3.4E-08		
Organics Pathway Total												9.8E-07	4.8E-08	4.4E-12	1.0E-06		R
Pathway Total - Chemicals						1.2E-02	7.5E-04			1.2E-05	1.3E-02	9.8E-07	4.8E-08	1.7E-09	1.0E-06		R
LAND USE/RECEPTOR: National Guard - Managed Recreational/Child Trespasser																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	1.5E-03	1.0E-04			5.6E-06	1.6E-03						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	8.9E-03	1.8E-04			2.1E-06	9.1E-03			2.1E-10	2.1E-10		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	1.3E-02	6.5E-04				1.3E-02						
Inorganics Pathway Total						2.3E-02	9.4E-04			7.6E-06	2.4E-02			2.1E-10	2.1E-10		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.0E-08	1.3E-09	5.9E-14	4.2E-08		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							2.8E-07	8.9E-09	4.1E-13	2.9E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.0E-08	1.3E-09	5.9E-14	4.2E-08		
Indeno(1,2,3-cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							1.2E-08	3.9E-10	1.8E-14	1.3E-08		
Organics Pathway Total												3.7E-07	1.2E-08	5.5E-13	3.9E-07		
Pathway Total - Chemicals						2.3E-02	9.4E-04			7.6E-06	2.4E-02	3.7E-07	1.2E-08	2.1E-10	3.9E-07		
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter-Trapper																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	7.7E-04	8.4E-05			9.0E-06	8.6E-04						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	4.6E-03	1.5E-04			3.3E-06	4.8E-03			1.7E-09	1.7E-09		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	6.6E-03	5.2E-04				7.2E-03						
Inorganics Pathway Total						1.2E-02	7.5E-04			1.2E-05	1.3E-02			1.7E-09	1.7E-09		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.1E-07	5.1E-09	4.7E-13	1.1E-07		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							7.3E-07	3.6E-08	3.3E-12	7.7E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.1E-07	5.1E-09	4.7E-13	1.1E-07		
Indeno(1,2,3-cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							3.2E-08	1.6E-09	1.4E-13	3.4E-08		
Organics Pathway Total												9.8E-07	4.8E-08	4.4E-12	1.0E-06		R
Pathway Total - Chemicals						1.2E-02	7.5E-04			1.2E-05	1.3E-02	9.8E-07	4.8E-08	1.7E-09	1.0E-06		R

Table 6-6. Sediment Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern Child/Ing.[a]	Chemical of Concern for Analyte[a]
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	1.4E-04	1.0E-04			1.1E-05	2.6E-04						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	8.6E-04	1.8E-04			4.1E-06	1.0E-03			1.7E-09	1.7E-09		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	1.2E-03	6.5E-04				1.9E-03						
Inorganics Pathway Total						2.2E-03	9.4E-04			1.5E-05	3.2E-03			1.7E-09	1.7E-09		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.6E-08	5.3E-09	4.9E-13	2.2E-08		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							1.1E-07	3.7E-08	3.4E-12	1.5E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							1.6E-08	5.3E-09	4.9E-13	2.2E-08		
Indeno(1,2,3-cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							5.0E-09	1.6E-09	1.5E-13	6.6E-09		
Organics Pathway Total												1.5E-07	4.9E-08	4.5E-12	2.0E-07		
Pathway Total - Chemicals						2.2E-03	9.4E-04			1.5E-05	3.2E-03	1.5E-07	4.9E-08	1.7E-09	2.0E-07		
LAND USE/RECEPTOR: Open Recreational/Recreator																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	6.4E-04	3.5E-05			3.7E-06	6.8E-04						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	3.9E-03	6.1E-05			1.4E-06	3.9E-03			6.9E-10	6.9E-10		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	5.5E-03	2.2E-04				5.7E-03						
Inorganics Pathway Total						1.0E-02	3.1E-04			5.1E-06	1.0E-02			6.9E-10	6.9E-10		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							8.8E-08	2.1E-09	2.0E-13	9.0E-08		
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							6.1E-07	1.5E-08	1.4E-12	6.3E-07		
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							8.8E-08	2.1E-09	2.0E-13	9.0E-08		
Indeno(1,2,3-cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							2.7E-08	6.5E-10	6.0E-14	2.7E-08		
Organics Pathway Total												8.1E-07	2.0E-08	1.8E-12	8.3E-07		
Pathway Total - Chemicals						1.0E-02	3.1E-04			5.1E-06	1.0E-02	8.1E-07	2.0E-08	7.0E-10	8.4E-07		
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																	
Barium	17/17	5.28E+02	2.01E+02	2.01E+02	UCL95	3.0E-03		3.9E-03	3.7E-02	4.2E-04	7.3E-03						
Chromium	17/17	2.13E+01	1.49E+01	1.49E+01	UCL95	1.8E-02		6.8E-03	6.4E-02	1.5E-04	2.5E-02			7.8E-08	7.8E-08		
Thallium	2/6	1.80E+00	1.42E+00	1.42E+00	UCL95	2.6E-02		2.4E-02	2.3E-01		5.0E-02						
Inorganics Pathway Total						4.7E-02		3.5E-02	3.3E-01	5.7E-04	8.2E-02			7.8E-08	7.8E-08		
Benzo(a)anthracene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.1E-07	6.4E-07	2.2E-11	1.1E-06		R
Benzo(a)pyrene	1/3	3.90E-01	4.59E-01	3.90E-01	Max Detect							2.9E-06	4.5E-06	1.5E-10	7.3E-06		R
Benzo(b)fluoranthene	1/3	5.60E-01	6.81E-01	5.60E-01	Max Detect							4.1E-07	6.4E-07	2.2E-11	1.1E-06		R
Indeno(1,2,3- cd)pyrene	1/3	1.70E-01	1.72E-01	1.70E-01	Max Detect							1.2E-07	1.9E-07	6.7E-12	3.2E-07		
Organics Pathway Total												3.8E-06	5.9E-06	2.0E-10	9.7E-06		R
Pathway Total - Chemicals						4.7E-02		3.5E-02	3.3E-01	5.7E-04	8.2E-02	3.8E-06	5.9E-06	7.8E-08	9.8E-06		R

[a] Chemical of concern codes: H = Hazard; R = Risk

Table 6-7. Surface Soil Direct Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Child Trespasser																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	2.0E-02	4.1E-04				2.1E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	4.0E-03	1.7E-03				5.6E-03	1.5E-07	6.4E-08	2.3E-10	2.2E-07		
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	4.0E-03	2.9E-04			1.5E-05	4.3E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	7.7E-01	7.8E-04				7.7E-01			4.4E-11	4.4E-11		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	1.3E-02	2.6E-04			3.0E-06	1.3E-02			3.0E-10	3.0E-10		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	5.3E-03	2.7E-04				5.5E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	4.2E-04	8.6E-05				5.1E-04						
Inorganics Pathway Total						8.1E-01	3.8E-03			1.8E-05	8.2E-01	1.5E-07	6.4E-08	5.8E-10	2.2E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	2.7E-04	1.8E-05				2.9E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	2.0E-01	1.2E-02				2.1E-01	2.5E-07	1.5E-08		2.7E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							2.8E-08	8.8E-10	4.1E-14	2.9E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							2.5E-07	7.8E-09	3.6E-13	2.5E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							3.0E-08	9.6E-10	4.4E-14	3.1E-08		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							7.9E-08	2.5E-09	1.2E-13	8.2E-08		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	2.3E-03	3.5E-05				2.3E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.8E-08	5.8E-10	2.7E-14	1.9E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	3.1E-02	3.2E-03				3.4E-02	8.8E-07	9.0E-08		9.6E-07		
Organics Pathway Total						2.3E-01	1.5E-02				2.5E-01	1.5E-06	1.2E-07	5.8E-13	1.6E-06		R
Pathway Total - Chemicals						1.0E+00	1.9E-02			1.8E-05	1.1E+00	1.7E-06	1.8E-07	5.8E-10	1.9E-06		R,H
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter-Trapper																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	1.1E-02	3.3E-04				1.1E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	2.1E-03	1.3E-03				3.4E-03	4.0E-07	2.6E-07	1.9E-09	6.6E-07		
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	2.1E-03	2.3E-04			2.4E-05	2.3E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	4.0E-01	6.3E-04				4.0E-01			3.6E-10	3.6E-10		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	6.7E-03	2.1E-04			4.8E-06	6.9E-03			2.4E-09	2.4E-09		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	2.7E-03	2.2E-04				3.0E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	2.2E-04	6.9E-05				2.9E-04						
Inorganics Pathway Total						4.2E-01	3.0E-03			2.9E-05	4.3E-01	4.0E-07	2.6E-07	4.6E-09	6.6E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	1.4E-04	1.4E-05				1.5E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.0E-01	9.7E-03				1.1E-01	6.6E-07	6.2E-08		7.2E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							7.3E-08	3.6E-09	3.3E-13	7.6E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							6.4E-07	3.1E-08	2.9E-12	6.7E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							7.9E-08	3.8E-09	3.5E-13	8.3E-08		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							2.1E-07	1.0E-08	9.3E-13	2.2E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	1.2E-03	2.8E-05				1.2E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							4.8E-08	2.3E-09	2.2E-13	5.0E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	1.6E-02	2.5E-03				1.9E-02	2.3E-06	3.6E-07		2.6E-06		R
Organics Pathway Total						1.2E-01	1.2E-02				1.3E-01	4.0E-06	4.7E-07	4.7E-12	4.5E-06		R
Pathway Total - Chemicals						5.4E-01	1.5E-02			2.9E-05	5.6E-01	4.4E-06	7.3E-07	4.6E-09	5.1E-06		R
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Security Guard - Maintenance Worker																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	1.8E-02	4.6E-04				1.8E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	3.4E-03	1.9E-03				5.3E-03	5.5E-07	3.0E-07	2.2E-09	8.5E-07		

Table 6-7. Surface Soil Direct Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.5E-03	3.2E-04			3.4E-05	3.8E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	6.6E-01	8.7E-04				6.6E-01			4.1E-10	4.1E-10		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	1.1E-02	2.9E-04			6.7E-06	1.1E-02			2.8E-09	2.8E-09		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	4.6E-03	3.0E-04				4.9E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	3.6E-04	9.6E-05				4.6E-04						
Inorganics Pathway Total						7.0E-01	4.2E-03			4.0E-05	7.1E-01	5.5E-07	3.0E-07	5.4E-09	8.6E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	2.3E-04	2.0E-05				2.5E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.7E-01	1.3E-02				1.8E-01	9.1E-07	7.2E-08		9.8E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.0E-07	4.1E-09	3.8E-13	1.0E-07		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							8.8E-07	3.6E-08	3.3E-12	9.2E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.1E-07	4.5E-09	4.1E-13	1.1E-07		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							2.9E-07	1.2E-08	1.1E-12	3.0E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	2.0E-03	3.9E-05				2.0E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							6.6E-08	2.7E-09	2.5E-13	6.9E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	2.7E-02	3.5E-03				3.0E-02	3.2E-06	4.2E-07		3.6E-06		R
Organics Pathway Total						2.0E-01	1.7E-02				2.2E-01	5.5E-06	5.5E-07	5.4E-12	6.1E-06		R
Pathway Total - Chemicals						9.0E-01	2.1E-02			4.0E-05	9.2E-01	6.1E-06	8.5E-07	5.4E-09	6.9E-06		R
LAND USE/RECEPTOR: National Guard - Managed Recreational/Child Trespasser																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	2.0E-02	4.1E-04				2.1E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	4.0E-03	1.7E-03				5.6E-03	1.5E-07	6.4E-08	2.3E-10	2.2E-07		
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	4.0E-03	2.9E-04			1.5E-05	4.3E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	7.7E-01	7.8E-04				7.7E-01			4.4E-11	4.4E-11		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	1.3E-02	2.6E-04			3.0E-06	1.3E-02			3.0E-10	3.0E-10		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	5.3E-03	2.7E-04				5.5E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	4.2E-04	8.6E-05				5.1E-04						
Inorganics Pathway Total						8.1E-01	3.8E-03			1.8E-05	8.2E-01	1.5E-07	6.4E-08	5.8E-10	2.2E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	2.7E-04	1.8E-05				2.9E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	2.0E-01	1.2E-02				2.1E-01	2.5E-07	1.5E-08		2.7E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							2.8E-08	8.8E-10	4.1E-14	2.9E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							2.5E-07	7.8E-09	3.6E-13	2.5E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							3.0E-08	9.6E-10	4.4E-14	3.1E-08		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							7.9E-08	2.5E-09	1.2E-13	8.2E-08		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	2.3E-03	3.5E-05				2.3E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.8E-08	5.8E-10	2.7E-14	1.9E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	3.1E-02	3.2E-03				3.4E-02	8.8E-07	9.0E-08		9.6E-07		
Organics Pathway Total						2.3E-01	1.5E-02				2.5E-01	1.5E-06	1.2E-07	5.8E-13	1.6E-06		R
Pathway Total - Chemicals						1.0E+00	1.9E-02			1.8E-05	1.1E+00	1.7E-06	1.8E-07	5.8E-10	1.9E-06		R,H
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter-Trapper																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	1.1E-02	3.3E-04				1.1E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	2.1E-03	1.3E-03				3.4E-03	4.0E-07	2.6E-07	1.9E-09	6.6E-07		
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	2.1E-03	2.3E-04			2.4E-05	2.3E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	4.0E-01	6.3E-04				4.0E-01			3.6E-10	3.6E-10		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	6.7E-03	2.1E-04			4.8E-06	6.9E-03			2.4E-09	2.4E-09		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	2.7E-03	2.2E-04				3.0E-03						

Table 6-7. Surface Soil Direct Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	2.2E-04	6.9E-05				2.9E-04						
Inorganics Pathway Total						4.2E-01	3.0E-03			2.9E-05	4.3E-01	4.0E-07	2.6E-07	4.6E-09	6.6E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	1.4E-04	1.4E-05				1.5E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.0E-01	9.7E-03				1.1E-01	6.6E-07	6.2E-08		7.2E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							7.3E-08	3.6E-09	3.3E-13	7.6E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							6.4E-07	3.1E-08	2.9E-12	6.7E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							7.9E-08	3.8E-09	3.5E-13	8.3E-08		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							2.1E-07	1.0E-08	9.3E-13	2.2E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	1.2E-03	2.8E-05				1.2E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							4.8E-08	2.3E-09	2.2E-13	5.0E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	1.6E-02	2.5E-03				1.9E-02	2.3E-06	3.6E-07		2.6E-06		R
Organics Pathway Total						1.2E-01	1.2E-02				1.3E-01	4.0E-06	4.7E-07	4.7E-12	4.5E-06		R
Pathway Total - Chemicals						5.4E-01	1.5E-02			2.9E-05	5.6E-01	4.4E-06	7.3E-07	4.6E-09	5.1E-06		R
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	1.3E-02	2.7E-03				1.5E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	2.5E-03	1.1E-02				1.3E-02	4.0E-07	1.7E-06	6.9E-06	9.0E-06		R
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	2.5E-03	1.8E-03			1.1E-01	1.1E-01						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	4.8E-01	5.0E-03				4.8E-01			1.3E-06	1.3E-06		R
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	8.0E-03	1.7E-03			2.1E-02	3.1E-02			8.9E-06	8.9E-06		R
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	3.3E-03	1.7E-03				5.0E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	2.6E-04	5.5E-04				8.1E-04						
Inorganics Pathway Total						5.1E-01	2.4E-02			1.3E-01	6.6E-01	4.0E-07	1.7E-06	1.7E-05	1.9E-05		R
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	1.7E-04	1.1E-04				2.8E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.2E-01	7.7E-02				2.0E-01	6.6E-07	4.1E-07		1.1E-06		R
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							7.2E-08	2.4E-08	1.2E-09	9.7E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							6.4E-07	2.1E-07	1.1E-08	8.6E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							7.8E-08	2.6E-08	1.3E-09	1.1E-07		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							2.1E-07	6.7E-08	3.4E-09	2.8E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	1.4E-03	2.3E-04				1.7E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							4.8E-08	1.6E-08	7.9E-10	6.4E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	1.9E-02	2.0E-02				4.0E-02	2.3E-06	2.4E-06		4.7E-06		R
Organics Pathway Total						1.4E-01	9.8E-02				2.4E-01	4.0E-06	3.2E-06	1.7E-08	7.1E-06		R
Pathway Total - Chemicals						6.5E-01	1.2E-01			1.3E-01	9.0E-01	4.4E-06	4.9E-06	1.7E-05	2.6E-05		R
LAND USE/RECEPTOR: Open Industrial/Industrial Worker																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	1.8E-02	1.1E-02				2.9E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	3.4E-03	4.5E-02				4.8E-02	5.5E-07	7.2E-06	5.2E-08	7.8E-06		R
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.5E-03	7.6E-03			8.1E-04	1.2E-02						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	6.6E-01	2.1E-02				6.8E-01			9.9E-09	9.9E-09		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	1.1E-02	7.0E-03			1.6E-04	1.8E-02			6.7E-08	6.7E-08		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	4.6E-03	7.2E-03				1.2E-02						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	3.6E-04	2.3E-03				2.7E-03						
Inorganics Pathway Total						7.0E-01	1.0E-01			9.7E-04	8.1E-01	5.5E-07	7.2E-06	1.3E-07	7.9E-06		R
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	2.3E-04	4.8E-04				7.1E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.7E-01	3.2E-01				4.9E-01	9.1E-07	1.7E-06		2.6E-06		R

Table 6-7. Surface Soil Direct Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.0E-07	9.9E-08	9.1E-12	2.0E-07		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							8.8E-07	8.7E-07	8.0E-11	1.8E-06		R
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.1E-07	1.1E-07	9.8E-12	2.2E-07		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							2.9E-07	2.8E-07	2.6E-11	5.7E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	2.0E-03	9.4E-04				2.9E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							6.6E-08	6.5E-08	6.0E-12	1.3E-07		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	2.7E-02	8.5E-02				1.1E-01	3.2E-06	1.0E-05		1.3E-05		R
Organics Pathway Total						2.0E-01	4.1E-01				6.1E-01	5.5E-06	1.3E-05	1.3E-10	1.9E-05		R
Pathway Total - Chemicals						9.0E-01	5.1E-01			9.7E-04	1.4E+00	6.1E-06	2.0E-05	1.3E-07	2.7E-05		R,H
LAND USE/RECEPTOR: Open Recreational/Recreator																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	8.8E-03	1.4E-04				9.0E-03						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	1.7E-03	5.6E-04				2.3E-03	3.3E-07	1.1E-07	7.8E-10	4.4E-07		
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	1.7E-03	9.6E-05			1.0E-05	1.8E-03						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	3.3E-01	2.6E-04				3.3E-01			1.5E-10	1.5E-10		
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	5.6E-03	8.8E-05			2.0E-06	5.7E-03			1.0E-09	1.0E-09		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	2.3E-03	9.0E-05				2.4E-03						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	1.8E-04	2.9E-05				2.1E-04						
Inorganics Pathway Total						3.5E-01	1.3E-03			1.2E-05	3.6E-01	3.3E-07	1.1E-07	1.9E-09	4.4E-07		
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	1.2E-04	5.9E-06				1.2E-04						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	8.5E-02	4.0E-03				8.9E-02	5.5E-07	2.6E-08		5.8E-07		
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							6.1E-08	1.5E-09	1.4E-13	6.2E-08		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							5.3E-07	1.3E-08	1.2E-12	5.5E-07		
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							6.6E-08	1.6E-09	1.5E-13	6.7E-08		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							1.7E-07	4.2E-09	3.9E-13	1.8E-07		
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	1.0E-03	1.2E-05				1.0E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							4.0E-08	9.8E-10	9.0E-14	4.1E-08		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	1.3E-02	1.1E-03				1.5E-02	1.9E-06	1.5E-07		2.1E-06		R
Organics Pathway Total						1.0E-01	5.1E-03				1.1E-01	3.3E-06	2.0E-07	2.0E-12	3.5E-06		R
Pathway Total - Chemicals						4.5E-01	6.4E-03			1.2E-05	4.6E-01	3.7E-06	3.0E-07	1.9E-09	4.0E-06		R
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																	
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.1E-02		1.6E-02	1.5E-01		5.7E-02						
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	8.1E-03		6.3E-02	5.8E-01		7.1E-02	1.6E-06	3.2E-05	8.7E-08	3.4E-05		R
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	8.1E-03		1.1E-02	1.0E-01	1.1E-03	2.0E-02						
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	1.6E+00		2.9E-02	2.7E-01		1.6E+00			1.7E-08	1.7E-08		H
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	2.6E-02		9.9E-03	9.2E-02	2.2E-04	3.6E-02			1.1E-07	1.1E-07		
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95	1.1E-02		1.0E-02	9.4E-02		2.1E-02						
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	8.5E-04		3.2E-03	3.0E-02		4.1E-03						
Inorganics Pathway Total						1.7E+00		1.4E-01	1.3E+00	1.4E-03	1.8E+00	1.6E-06	3.2E-05	2.2E-07	3.4E-05	H	R,H
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	5.4E-04		6.7E-04	6.2E-03		1.2E-03						
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	4.0E-01		4.5E-01	4.2E+00		8.5E-01	2.6E-06	7.7E-06		1.0E-05	H	R
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							2.8E-07	4.4E-07	1.5E-11	7.3E-07		
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							2.5E-06	3.9E-06	1.3E-10	6.4E-06		R
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							3.1E-07	4.8E-07	1.7E-11	7.9E-07		
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							8.1E-07	1.3E-06	4.3E-11	2.1E-06		R

Table 6-7. Surface Soil Direct Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	4.7E-03		1.3E-03	1.2E-02		6.0E-03						
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.9E-07	2.9E-07	1.0E-11	4.8E-07		
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	6.3E-02		1.2E-01	1.1E+00		1.8E-01	8.9E-06	4.5E-05		5.4E-05	H	R
Organics Pathway Total						4.7E-01		5.7E-01	5.3E+00		1.0E+00	1.6E-05	5.9E-05	2.2E-10	7.4E-05	H	R,H
Pathway Total - Chemicals						2.1E+00		7.1E-01	6.7E+00	1.4E-03	2.8E+00	1.7E-05	9.1E-05	2.2E-07	1.1E-04	H	R,H

[a] Chemical of concern codes: H = Hazard; R = Risk

The child trespasser is the only receptor without COCs from the direct contact with surface soil. Although its total risk across all chemicals and all pathways was 1.9E-06, there are no chemicals with total risk > 1.0E-06 for the child trespasser exposed directly to surface soil. Similarly, although its HI across all chemicals and all pathways is 1.1, no chemical's HI is > 1.0 for the child trespasser exposed directly to surface soil. Consequently, there are no COCs for the child trespasser exposed directly to surface soil.

The explosive RDX is a COC for all six of the remaining receptors exposed directly to surface soil. Its total cancer risk comes predominantly from the dermal contact pathway and sometimes from the ingestion pathway (depending on the ingestion rate for the receptor). It is the only COC for the hunter/trapper (total risk of 2.6E-06), the security guard/maintenance worker (total risk of 3.6E-06), and for the recreator (total risk of 2.1E-06). The total risks across all COPCs (not just RDX) are 5.1E-06, 6.9E-06, and 4.0E-06 for the hunter/trapper, security guard/maintenance worker, and the recreator, respectively.

Five carcinogenic COCs are identified for the National Guard exposed directly to surface soils; no noncarcinogenic COCs are identified for this receptor. COCs for the National Guard exposed directly to surface soil include arsenic (total risk of 9.0E-06, mostly from inhalation and ingestion), cadmium (total risk of 1.3E-06, from inhalation), chromium (total risk of 8.9E-06, from inhalation), TNT (total risk of 1.1E-06, from dermal contact and ingestion), and RDX (total risk of 4.7E-06, from ingestion and dermal contact). Total risk across all COPCs is 2.6E-05 for the National Guard receptor, with contributions from dermal contact (4.4E-06), ingestion (4.9E-06), and inhalation (1.7E-05).

Four carcinogenic COCs are identified for the industrial worker exposed directly to surface soils; no noncarcinogenic COCs are identified for this receptor. Arsenic (total risk of 7.8E-06, mostly from ingestion), TNT (total risk of 2.6E-06, from ingestion and dermal contact), benzo(a)pyrene (total risk of 1.8E-06, mostly from dermal contact and ingestion), and RDX (total risk of 1.3E-05, from ingestion and dermal contact) are identified as COCs for the industrial worker exposed directly to surface soil. Total risk across all COPCs is 2.7E-05.

Six COCs are identified for the on-site resident farmer exposed directly to surface soil. Cadmium (HI of 1.6, predominantly from dermal contact), TNT (child ingestion HQ of 4.2), and RDX (child ingestion HQ of 1.1) are identified as noncarcinogenic COCs. Carcinogenic COCs for the on-site resident farmer exposed directly to surface soil include arsenic (total risk of 3.4E-05, mostly from ingestion and dermal contact), TNT (total risk of 1.0E-05, from ingestion and dermal contact), benzo(*a*)pyrene (total risk of 6.4E-06, mostly from ingestion and dermal contact), dibenzo(*a,h*)anthracene (total risk of 2.1E-06, mostly from ingestion and dermal contact), and RDX (total risk of 5.4E-05, from ingestion and dermal contact). Total risk across all COPCs for the on-site resident farmer is 1.1E-04, coming predominately from dermal contact (1.7E-05) and ingestion 9.1.E-05.

6.5.2.1.4.1 Alternative risk evaluation for surface soil aggregate, direct contact

A risk evaluation based on slightly different screening criteria is performed for the direct exposure to surface soil. As discussed in Section 6.2.1.1, the SRC screening process involved several steps, including a step to remove from consideration those metals with less than 5 percent of their sample results detected above their background concentration. As a result of this screening step, manganese (detected above background in 7/149 samples) and vanadium (detected above background in 3/77 samples) have been eliminated as SRCs and thus, have not been evaluated in the aggregate risk results as presented in Section 6.5.2.1.4. This section presents a risk evaluation for surface soil that includes these two metals as SRCs, describing the effect of including these two SRCs on the conclusions drawn in the previous evaluation.

As seen from **Table J.2.4**, which provides summary statistics and screening information for surface soil data, the maximum detected concentration for manganese is 3910 mg/kg and the residential risk-based screening value (i.e., $1/10^{th}$ EPA Region IX PRG) is 312 mg/kg. Since the maximum detected concentration is larger than the screening value, manganese is considered a COPC for this risk evaluation. Since the maximum detected concentration for vanadium (34 mg/kg) is smaller than its residential risk-based screening value (52.5 mg/kg), vanadium is eliminated from the COPC list for this risk evaluation.

Since manganese does not currently have a cancer slope factor and is the only additional COPC in this risk evaluation, there are no changes to the conclusions regarding cancer risks for the direct exposure to surface soil (as compared to the results of the risk evaluation presented in Section 6.5.2.1.4). Therefore, looking at the noncarcinogenic hazards depicts the net effect of including manganese in this risk evaluation.

The total HI for manganese (i.e., the increase in the previous total hazard index across all chemicals and across all pathways/routes of exposure) for each receptor and the next effect is as follows:

- Child trespasser: manganese HI=0.012; no change in COCs.
- Hunter/trapper: manganese HI=0.0068; no change in COCs.
- Security guard/maintenance worker: manganese HI=0.011; no change in COCs.
- National Guard: manganese HI=1.20; manganese becomes a COC.
- Industrial worker: manganese HI=0.032; no change in COCs.
- Recreator: manganese HI=0.0054; no change in COCs.
- On-site resident farmer: manganese HI=0.054; child ingestion HQ=0.17; no change in COCs.

As seen, by including manganese in this risk evaluation, the only change in conclusions (from the risk evaluation presented in Section 6.5.2.1.4) is for the National Guard receptor. The use of a higher dust loading factor for the National Guard receptor results in a larger inhalation HQ for this receptor than for all other receptors (this same dust loading factor is used in the risk evaluation presented in Section 6.5.2.1.4). Consequently, manganese becomes a COC in this risk evaluation. Again, this risk evaluation is presented for informational purposes only. The results from the surface soil risk evaluation as presented in Section 6.5.2.1.4 (i.e., without manganese) are used in this BHHRA to form conclusions and recommendations for the AOC.

6.5.2.1.5 Surface soil aggregate, indirect contact

Table 6-8 presents the risks and hazards for the two receptors that have been evaluated for indirect contact with surface soil (i.e., ingestion of foodstuffs after uptake into plants and/or animals from the surface soil). One of these receptors, the hunter/trapper, is evaluated for two different land uses (the Maintained Industrial/Managed Recreational and the National Guard/ Managed Recreational land uses), based on the ingestion of venison. The other receptor, the on-site resident farmer, is evaluated for the ingestion of venison, beef, milk, and vegetables.

The hunter/trapper receptor produces no hazards > 1 and no risks > 10^{-6} when evaluating the ingestion of venison; thus there are no COCs for the hunter/trapper exposed indirectly to surface soils at the WBG.

Many COCs are identified for the on-site resident farmer exposed indirectly to surface soils (total risk is 1.1E-02, and total HI is 310). Chemicals with total risks (from ingestion of all four types of foods) >10^{-6} include:

- Arsenic (total risk of 2.8E-3, mostly from ingestion of vegetables, with risks from ingestion of beef and milk also contributing risks > 10^{-6});

Table 6-8. Surface Soil Indirect (Foodstuffs) Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Expos. Point Conc. (mg/kg)	Statistic for EPC	Ingest. Venison HQ	Ingest. Beef HQ	Ingest. Milk HQ Adult	Ingest. Milk HQ Child	Ingest. Veg. HQ	Total HI	Ingest. Venison Risk	Ingest. Beef Risk	Ingest. Milk Risk	Ingest. Veg. Risk	Total Risk	COC Venison[a]	COC Milk/ Overall[a]	COC Milk/ Adult[a]	COC Milk/ Child[a]	COC Veget.[a]	COC for Analyte[a]
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter-Trapper																						
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06					4.9E-06											
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	7.9E-04					7.9E-04	1.5E-07				1.5E-07						
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.4E-05					3.4E-05											
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	1.0E-03					1.0E-03											
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	5.6E-04					5.6E-04											
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95																	
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	5.0E-02					5.0E-02											
Inorganics Pathway Total						5.2E-02					5.2E-02	1.5E-07				1.5E-07						
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	6.5E-08					6.5E-08											
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.3E-04					1.3E-04	8.3E-10				8.3E-10						
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.3E-09				1.3E-09						
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							1.6E-08				1.6E-08						
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.9E-09				1.9E-09						
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							1.0E-08				1.0E-08						
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	6.9E-08					6.9E-08											
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.9E-09				1.9E-09						
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	8.6E-05					8.6E-05	1.2E-08				1.2E-08						
Organics Pathway Total						2.2E-04					2.2E-04	4.4E-08				4.4E-08						
Pathway Total						5.3E-02					5.3E-02	2.0E-07				2.0E-07						
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter-Trapper																						
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06					4.9E-06											
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	7.9E-04					7.9E-04	1.5E-07				1.5E-07						
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.4E-05					3.4E-05											
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	1.0E-03					1.0E-03											
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	5.6E-04					5.6E-04											
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95																	
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	5.0E-02					5.0E-02											
Inorganics Pathway Total						5.2E-02					5.2E-02	1.5E-07				1.5E-07						
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	6.5E-08					6.5E-08											
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.3E-04					1.3E-04	8.3E-10				8.3E-10						
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.3E-09				1.3E-09						
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							1.6E-08				1.6E-08						
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.9E-09				1.9E-09						
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							1.0E-08				1.0E-08						
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	6.9E-08					6.9E-08											
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.9E-09				1.9E-09						
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	8.6E-05					8.6E-05	1.2E-08				1.2E-08						
Organics Pathway Total						2.2E-04					2.2E-04	4.4E-08				4.4E-08						
Pathway Total						5.3E-02					5.3E-02	2.0E-07				2.0E-07						
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																						
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06	1.4E-03	4.8E-03	3.8E-02	3.5E+00	3.5E+00										H	H

Table 6-8. Surface Soil Indirect (Foodstuffs) Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Expos. Point Conc. (mg/kg)	Statistic for EPC	Ingest. Venison HQ	Ingest. Beef HQ	Ingest. Milk HQ Adult	Ingest. Milk HQ Child	Ingest. Veg. HQ	Total HI	Ingest. Venison Risk	Ingest. Beef Risk	Ingest. Milk Risk	Ingest. Veg. Risk	Total Risk	COC Venison[d]	COC Milk/ Overall[d]	COC Milk/ Adult[a]	COC Milk/ Child[a]	COC Veget.[a]
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter-Trapper																					
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06					4.9E-06										
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	7.9E-04					7.9E-04	1.5E-07				1.5E-07					
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.4E-05					3.4E-05										
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	1.0E-03					1.0E-03										
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	5.6E-04					5.6E-04										
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95																
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	5.0E-02					5.0E-02										
Inorganics Pathway Total						5.2E-02					5.2E-02	1.5E-07				1.5E-07					
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	6.5E-08					6.5E-08										
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.3E-04					1.3E-04	8.3E-10				8.3E-10					
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.3E-09				1.3E-09					
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							1.6E-08				1.6E-08					
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.9E-09				1.9E-09					
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							1.0E-08				1.0E-08					
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	6.9E-08					6.9E-08										
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.9E-09				1.9E-09					
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	8.6E-05					8.6E-05	1.2E-08				1.2E-08					
Organics Pathway Total						2.2E-04					2.2E-04	4.4E-08				4.4E-08					
Pathway Total						5.3E-02					5.3E-02	2.0E-07				2.0E-07					
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter-Trapper																					
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06					4.9E-06										
Arsenic	149/149	3.58E+01	1.37E+01	1.37E+01	UCL95	7.9E-04					7.9E-04	1.5E-07				1.5E-07					
Barium	148/149	1.04E+04	5.47E+02	5.47E+02	UCL95	3.4E-05					3.4E-05										
Cadmium	102/148	8.77E+02	2.14E+01	2.14E+01	UCL95	1.0E-03					1.0E-03										
Chromium	149/149	1.89E+02	2.16E+01	2.16E+01	UCL95	5.6E-04					5.6E-04										
Thallium	7/77	3.10E+00	5.89E-01	5.89E-01	UCL95																
Zinc	149/149	2.49E+04	7.04E+02	7.04E+02	UCL95	5.0E-02					5.0E-02										
Inorganics Pathway Total						5.2E-02					5.2E-02	1.5E-07				1.5E-07					
1,3,5-Trinitrobenzene	15/99	4.90E+02	1.46E+01	1.46E+01	UCL95	6.5E-08					6.5E-08										
2,4,6-Trinitrotoluene	29/99	3.80E+03	1.65E+02	1.65E+02	UCL95	1.3E-04					1.3E-04	8.3E-10				8.3E-10					
Benzo(a)anthracene	4/14	1.00E+00	3.87E-01	3.87E-01	UCL95							1.3E-09				1.3E-09					
Benzo(a)pyrene	4/14	8.00E-01	3.40E-01	3.40E-01	UCL95							1.6E-08				1.6E-08					
Benzo(b)fluoranthene	4/14	1.10E+00	4.19E-01	4.19E-01	UCL95							1.9E-09				1.9E-09					
Dibenzo(a,h)anthracene	2/14	1.10E-01	2.08E-01	1.10E-01	Max Detect							1.0E-08				1.0E-08					
HMX	14/99	1.70E+03	4.81E+01	4.81E+01	UCL95	6.9E-08					6.9E-08										
Indeno(1,2,3-cd)pyrene	3/14	4.80E-01	2.55E-01	2.55E-01	UCL95							1.9E-09				1.9E-09					
RDX	10/99	9.50E+03	2.60E+02	2.60E+02	UCL95	8.6E-05					8.6E-05	1.2E-08				1.2E-08					
Organics Pathway Total						2.2E-04					2.2E-04	4.4E-08				4.4E-08					
Pathway Total						5.3E-02					5.3E-02	2.0E-07				2.0E-07					
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																					
Antimony	38/77	2.79E+01	4.54E+00	4.54E+00	UCL95	4.9E-06	1.4E-03	4.8E-03	3.8E-02	3.5E+00	3.5E+00										H

- TNT (total risk of 1.5E-3, mostly from ingestion of vegetables);
- Benzo(*a*)anthracene (total risk of 5.9E-5, mostly from ingestion of vegetables, milk, and beef);
- Benzo(*a*)pyrene (total risk of 7.9E-4, mostly from ingestion of milk and vegetables, with risk from ingestion of beef also > 10^{-6});
- Benzo(*b*)fluoranthene (total risk of 9.8E-5, mostly from ingestion of milk, vegetables, and beef);
- Dibenzo(*a,h*)anthracene (total risk of 8.7E-4, mostly from ingestion of milk, beef, and vegetables);
- Indeno(1,2,3-*cd*)pyrene (total risk of 1.3E-4, mostly from ingestion of milk, vegetables, and beef); and
- RDX (total risk of 5.0E-3, mostly from ingestion of vegetables, with risks from ingestion of milk and beef also contributing risks > 10^{-6}).

Chemicals with total hazards (from ingestion of all four types of foods) >1 for the on-site resident farmer exposed indirectly to surface soils include:

- Antimony (total HI of 3.5, predominantly from the ingestion of vegetables);
- Arsenic (total HI of 14, predominantly from the ingestion of vegetables);
- Barium (total HI of 2.4, predominantly from the ingestion of vegetables);
-
- Cadmium (total HI of 11, predominantly from the ingestion of vegetables; HQ of 6.3 for the child's ingestion of milk);
- Chromium (total HI of 2.3, predominantly from the ingestion of vegetables);
- Zinc (total HI of 5.0, predominantly from the ingestion of beef, vegetables, and milk; HQ of 10 for the child's ingestion of milk);
- TNB (total HI of 1.0, predominantly from the ingestion of vegetables);
- TNT (total HI of 230, predominantly from the ingestion of vegetables);
- HMX (total HI of 4.1, predominantly from the ingestion of vegetables); and
- RDX (total HI of 35, predominantly from the ingestion of vegetables).

6.5.2.1.6 Subsurface soil aggregate

Table 6-9 presents the risks and hazards for the three receptors that have been evaluated for direct contact with subsurface soil. These receptors include the National Guard, the industrial worker, and the on-site resident farmer. As discussed in Sect. 6.2.2, the subsurface soil data set for this BHHRA includes soil data ranging from sampling depths of 0 to 1.9 m (0 to 6 feet). The exposure point concentration is the smaller concentration when comparing the UCL_{95} on the mean and the maximum detected concentration (see Section 6.4.3).

Table 6-9. Subsurface Soil Risks and Hazards from Aggregated Data

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																	
Antimony	51/108	2.79E+01	3.40E+00	3.40E+00	UCL95	1.5E-03	3.1E-04				1.8E-03						
Barium	179/180	1.04E+04	4.73E+02	4.73E+02	UCL95	3.3E-04	2.5E-04			2.6E-05	6.1E-04						
Cadmium	106/179	8.77E+02	1.79E+01	1.79E+01	UCL95	6.2E-02	6.5E-04				6.3E-02			3.1E-10	3.1E-10		
Chromium	180/180	1.89E+02	2.08E+01	2.08E+01	UCL95	1.2E-03	2.5E-04			5.8E-06	1.5E-03			2.4E-09	2.4E-09		
Thallium	10/108	3.10E+00	5.25E-01	5.25E-01	UCL95	4.5E-04	2.4E-04				6.9E-04						
Zinc	180/180	2.49E+04	5.96E+02	5.96E+02	UCL95	3.4E-05	7.3E-05				1.1E-04						
Inorganics Pathway Total						6.5E-02	1.8E-03			3.2E-05	6.7E-02			2.7E-09	2.7E-09		
1,3,5-Trinitrobenzene	32/130	4.90E+02	1.12E+01	1.12E+01	UCL95	2.0E-05	1.4E-05				3.4E-05						
2,4,6-Trinitrotoluene	49/130	3.80E+03	1.26E+02	1.26E+02	UCL95	1.5E-02	9.2E-03				2.4E-02	7.8E-08	4.9E-08		1.3E-07		
Benzo(a)anthracene	6/23	1.00E+00	3.20E-01	3.20E-01	UCL95							9.3E-09	3.0E-09	2.8E-13	1.2E-08		
Benzo(a)pyrene	6/23	8.00E-01	2.94E-01	2.95E-01	UCL95							8.6E-08	2.8E-08	2.6E-12	1.1E-07		
Benzo(b)fluoranthene	6/23	1.10E+00	3.55E-01	3.55E-01	UCL95							1.0E-08	3.4E-09	3.1E-13	1.4E-08		
Dibenzo(a,h)anthracene	3/23	1.10E-01	2.00E-01	1.10E-01	Max Detect							3.2E-08	1.0E-08	9.6E-13	4.3E-08		
HMX	32/130	1.70E+03	3.68E+01	3.68E+01	UCL95	1.7E-04	2.7E-05				2.0E-04						
Indeno(1,2,3-cd)pyrene	4/23	4.80E-01	2.42E-01	2.42E-01	UCL95							7.0E-09	2.3E-09	2.1E-13	9.3E-09		
RDX	23/130	9.50E+03	1.99E+02	1.99E+02	UCL95	2.3E-03	2.4E-03				4.7E-03	2.7E-07	2.9E-07		5.6E-07		
Organics Pathway Total						1.7E-02	1.2E-02				2.9E-02	4.9E-07	3.8E-07	4.3E-12	8.7E-07		
Pathway Total - Chemicals						8.2E-02	1.3E-02			3.2E-05	9.6E-02	4.9E-07	3.8E-07	2.7E-09	8.8E-07		
LAND USE/RECEPTOR: Open Industrial/Industrial Worker																	
Antimony	51/108	2.79E+01	3.40E+00	3.40E+00	UCL95	1.3E-02	8.3E-03				2.1E-02						
Barium	179/180	1.04E+04	4.73E+02	4.73E+02	UCL95	3.0E-03	6.6E-03			7.0E-04	1.0E-02						
Cadmium	106/179	8.77E+02	1.79E+01	1.79E+01	UCL95	5.5E-01	1.8E-02				5.7E-01			8.3E-09	8.3E-09		
Chromium	180/180	1.89E+02	2.08E+01	2.08E+01	UCL95	1.1E-02	6.8E-03			1.5E-04	1.8E-02			6.4E-08	6.4E-08		
Thallium	10/108	3.10E+00	5.25E-01	5.25E-01	UCL95	4.1E-03	6.4E-03				1.0E-02						
Zinc	180/180	2.49E+04	5.96E+02	5.96E+02	UCL95	3.1E-04	1.9E-03				2.2E-03						
Inorganics Pathway Total						5.8E-01	4.8E-02			8.6E-04	6.3E-01			7.3E-08	7.3E-08		
1,3,5-Trinitrobenzene	32/130	4.90E+02	1.12E+01	1.12E+01	UCL95	1.8E-04	3.7E-04				5.4E-04						
2,4,6-Trinitrotoluene	49/130	3.80E+03	1.26E+02	1.26E+02	UCL95	1.3E-01	2.5E-01				3.8E-01	7.0E-07	1.3E-06		2.0E-06		R
Benzo(a)anthracene	6/23	1.00E+00	3.20E-01	3.20E-01	UCL95							8.3E-08	8.2E-08	7.5E-12	1.6E-07		
Benzo(a)pyrene	6/23	8.00E-01	2.94E-01	2.95E-01	UCL95							7.7E-07	7.5E-07	6.9E-11	1.5E-06		R
Benzo(b)fluoranthene	6/23	1.10E+00	3.55E-01	3.55E-01	UCL95							9.2E-08	9.0E-08	8.3E-12	1.8E-07		
Dibenzo(a,h)anthracene	3/23	1.10E-01	2.00E-01	1.10E-01	Max Detect							2.9E-07	2.8E-07	2.6E-11	5.7E-07		
HMX	32/130	1.70E+03	3.68E+01	3.68E+01	UCL95	1.5E-03	7.2E-04				2.2E-03						
Indeno(1,2,3-cd)pyrene	4/23	4.80E-01	2.42E-01	2.42E-01	UCL95							6.3E-08	6.2E-08	5.7E-12	1.2E-07		
RDX	23/130	9.50E+03	1.99E+02	1.99E+02	UCL95	2.0E-02	6.5E-02				8.5E-02	2.4E-06	7.6E-06		1.0E-05		R
Organics Pathway Total						1.5E-01	3.1E-01				4.7E-01	4.4E-06	1.0E-05	1.2E-10	1.5E-05		R
Pathway Total - Chemicals						7.4E-01	3.6E-01			8.6E-04	1.1E+00	4.4E-06	1.0E-05	7.3E-08	1.5E-05		R,H
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																	
Antimony	51/108	2.79E+01	3.40E+00	3.40E+00	UCL95	3.1E-02		1.2E-02	1.1E-01		4.3E-02						
Barium	179/180	1.04E+04	4.73E+02	4.73E+02	UCL95	7.0E-03		9.3E-03	8.6E-02	9.8E-04	1.7E-02						
Cadmium	106/179	8.77E+02	1.79E+01	1.79E+01	UCL95	1.3E+00		2.5E-02	2.3E-01		1.3E+00			1.4E-08	1.4E-08		H
Chromium	180/180	1.89E+02	2.08E+01	2.08E+01	UCL95	2.5E-02		9.5E-03	8.9E-02	2.2E-04	3.5E-02			1.1E-07	1.1E-07		

Table 6-9. Subsurface Soil Risks and Hazards from Aggregated Data (continued)

Analyte	Results >Detection Limit	Maximum Detect (mg/kg)	95% UCL on Mean (mg/kg)	Exposure Point Conc. (mg/kg)	Statistic for EPC	Dermal HQ	Ingestion HQ (one receptor)	Ingestion HQ Adult	Ingestion HQ Child	Inhalation HQ	Total HI across all pathways	Dermal Risk	Ingestion Risk	Inhalation Risk	Total Risk across all pathways	Chemical of Concern for Child Ingestion[a]	Chemical of Concern for Analyte[a]
Thallium	10/108	3.10E+00	5.25E-01	5.25E-01	UCL95	9.5E-03		9.0E-03	8.4E-02		1.9E-02						
Zinc	180/180	2.49E+04	5.96E+02	5.96E+02	UCL95	7.2E-04		2.7E-03	2.5E-02		3.4E-03						
Inorganics Pathway Total						1.4E+00		6.7E-02	6.2E-01	1.2E-03	1.4E+00			1.2E-07	1.2E-07		H
1,3,5-Trinitrobenzene	32/130	4.90E+02	1.12E+01	1.12E+01	UCL95	4.2E-04		5.1E-04	4.8E-03		9.3E-04						
2,4,6-Trinitrotoluene	49/130	3.80E+03	1.26E+02	1.26E+02	UCL95	3.1E-01		3.5E-01	3.2E+00		6.5E-01	2.0E-06	5.9E-06		7.9E-06	H	R
Benzo(a)anthracene	6/23	1.00E+00	3.20E-01	3.20E-01	UCL95							2.3E-07	3.7E-07	1.3E-11	6.0E-07		
Benzo(a)pyrene	6/23	8.00E-01	2.94E-01	2.95E-01	UCL95							2.2E-06	3.4E-06	1.2E-10	5.5E-06		R
Benzo(b)fluoranthene	6/23	1.10E+00	3.55E-01	3.55E-01	UCL95							2.6E-07	4.1E-07	1.4E-11	6.6E-07		
Dibenzo(a,h)anthracene	3/23	1.10E-01	2.00E-01	1.10E-01	Max Detect							8.1E-07	1.3E-06	4.3E-11	2.1E-06		R
HMX	32/130	1.70E+03	3.68E+01	3.68E+01	UCL95	3.6E-03		1.0E-03	9.4E-03		4.6E-03						
Indeno(1,2,3-cd)pyrene	4/23	4.80E-01	2.42E-01	2.42E-01	UCL95							1.8E-07	2.8E-07	9.5E-12	4.5E-07		
RDX	23/130	9.50E+03	1.99E+02	1.99E+02	UCL95	4.8E-02		9.1E-02	8.5E-01		1.4E-01	6.8E-06	3.4E-05		4.1E-05		R
Organics Pathway Total						3.6E-01		4.4E-01	4.1E+00		8.0E-01	1.2E-05	4.6E-05	2.0E-10	5.8E-05	H	R
Pathway Total - Chemicals						1.7E+00		5.0E-01	4.7E+00	1.2E-03	2.2E+00	1.2E-05	4.6E-05	1.2E-07	5.8E-05	H	R,H

[a] Chemical of concern codes: H = Hazard; R = Risk

No COCs are identified for the National Guard receptor exposed to subsurface soil. Total HI across all analytes and all pathways is 0.096 and total risk across all analytes and all pathways is 8.8E-07.

For the industrial worker exposed to subsurface soil, three carcinogenic COCs are identified (total risk across all COPCs is 1.5E-05). No noncarcinogenic COCs are identified (while the total HI across all analytes and pathways is 1.1, the largest HI for an individual chemical is 0.57). The three subsurface soil carcinogenic COCs are TNT (total risk of 2.0E-6, mostly from ingestion), benzo(*a*)pyrene (total risk of 1.5E-6, mostly from dermal contact and ingestion), and RDX (total risk of 1.0E-5, from ingestion and dermal contact).

For the on-site resident farmer exposed to subsurface soil, five COCs are identified, including one (TNT) that is both a noncarcinogenic and carcinogenic COC. Cadmium (HI of 1.3, predominantly from dermal contact) and TNT (HI of 3.2 for child ingestion) are the two noncarcinogenic COCs. Carcinogenic COCs include TNT (total risk of 7.9E-6, from ingestion and dermal contact), benzo(*a*)pyrene (total risk of 5.5E-6, mostly from ingestion and dermal contact), dibenzo(*a,h*)anthracene (total risk of 2.1E-6, mostly from ingestion) and RDX (total risk of 4.1E-5, from ingestion and dermal contact). The total risk across all COPCs is 5.8E-05, coming mostly from dermal contact (1.2E-05) and ingestion (4.6E-05).

6.5.2.1.6.1 Alternative risk evaluation for subsurface soil aggregate

A risk evaluation based on slightly different screening criteria is performed for the exposure to subsurface soil. As discussed in Section 6.2.1.1, the SRC screening process involved several steps, including a step to remove from consideration those metals with less than 5 percent of their sample results detected above their background concentration. As a result of this screening step, six metals have been eliminated as SRCs and thus, have not been evaluated in the aggregate risk results as presented in Section 6.5.2.1.6. These metals are aluminum (detected above background in 9/180 samples), arsenic (detected above background in 7/180 samples), cobalt (detected above background in 1/108 samples), manganese (detected above background in 3/180 samples), nickel (detected above background in 1/108 samples), and vanadium (detected above background in 1/108 samples). This Section presents a risk evaluation for subsurface soil that includes these six metals as SRCs, describing the effect of including these two SRCs on the conclusions drawn in the previous evaluation.

To evaluate which of these six SRCs become COPCs, their maximum detected concentrations are compared against the residential risk-based screening value (i.e., $1/10^{th}$ EPA Region IX PRG). As seen from **Table J.2.5**, which provides summary statistics and screening information for subsurface soil data, the maximum detected concentration exceeds the residential RBSC for aluminum, arsenic, and manganese, but not for cobalt, nickel, and vanadium. Therefore, aluminum, arsenic, and manganese are considered COPCs for this risk evaluation, while cobalt, nickel, and vanadium have been eliminated from the COPC list for this risk evaluation.

Since aluminum has no toxicity values available and is detected at relatively low concentrations, no attempt is made to quantify risks/hazards for this chemical in this risk evaluation. Since arsenic has both carcinogenic and noncarcinogenic toxicity values available and since manganese has noncarcinogenic toxicity values available, both risks and hazards are expected to increase (as compared to the results of the previous risk evaluation, as presented in Section 6.5.2.1.6).

The change in risks and hazards and the net effect of including arsenic and manganese in this risk evaluation is presented below each receptor:

1. National Guard:
   - arsenic Risk=3.3E-07;
   - arsenic HI=2.1E-03;
   - manganese HI=2.0E-03; no change in COCs.
2. Industrial worker:
   - arsenic Risk=7.8E-06;
   - arsenic HI=4.8E-02;
   - manganese HI=3.3E-02; arsenic becomes carcinogenic COC.
3. On-site resident farmer:
   - arsenic Risk=3.4E-05;
   - arsenic HI=7.1E-02;
   - manganese HI=5.6E-02; arsenic becomes carcinogenic COC.

As seen, by including arsenic and manganese in this risk evaluation, the only change in conclusions (from the risk evaluation presented in Section 6.5.2.1.6) is that arsenic becomes a carcinogenic COC for the industrial worker and for the on-site resident farmer in this risk evaluation. Again, this risk evaluation is presented for informational purposes only. The results from the subsurface soil risk evaluation as presented in Section 6.5.2.1.6 (i.e., without arsenic and manganese) are used in this BHHRA to form conclusions and recommendations for the AOC.

6.5.2.1.7 Summary of COCs across all media/receptors

Table 6-10 presents a summary of the 13 land use/receptor/medium combinations that have COCs in this BHHRA (there are 23 land use/receptor/medium combinations where risk and/or hazards are calculated for this BHHRA). To further evaluate the results of this aggregate risk evaluation, a location-by-location risk evaluation is presented in Section 6.5.2.2. RGOs are calculated and presented in Section 6.5.3 for the 17 COCs identified in the aggregate risk evaluation.

Since risks > 10^{-4} are unacceptable and HIs > 1.0 are defined as the level of concern for potential adverse noncarcinogenic health effects (see Section 6.5.1), chemicals meeting these criteria are identified as being COCs with large risks/hazards for WBG. The COCs with large risks/hazards and the pathways/foodstuffs that contribute significantly to their total risk/HI are identified in **Table 6-11**. As seen from **Table 6-11**, there are 14 COCs with large risks/hazards, all for the on-site resident farmer receptor. These COCs are from exposures to groundwater (manganese), direct contact with surface soil (cadmium; TNT; and RDX), ingestion of foodstuffs [antimony; arsenic; barium; cadmium; chromium; zinc; TNB; TNT; benzo(*a*)pyrene; dibenzo(*a,h*)anthracene; HMX; Indeno(1,2,3-*cd*)pyrene; and RDX], and direct contact with subsurface soil (cadmium and TNT).

For information only, the total risks for each medium are summed for each receptor; similarly, the total hazard indexes for each medium are summed for each receptor. (Note that the determination of COCs is not based on this summation; COCs are determined for each medium/receptor combination). The carcinogenic risks across all media are shown for the receptors in **Table 6-12**. As seen the total risk across all media exceeds 1.0E-06 for all receptors. The total risk across all media for the resident farmer adult exceeds 1.0E-04, mostly from the ingestion of vegetables, beef, and milk. The noncarcinogenic hazards across all media are shown for the receptors in **Table 6-13**. Three receptors (security guard/maintenance worker, hunter/trapper, and the recreator) have total hazards < 1.0, while all of the other receptors have hazards > 1.0. Not surprisingly (based on the exposure parameters used), the resident farmer adult and child have the largest total hazards (320 and 29, respectively).

Table 6-10. Land Use/Receptor/Medium Combinations With COCs[a]

CHEMICAL OF CONCERN	GROUNDWATER		SEDIMENT	SUB-SURFACE SOIL		SURFACE SOIL/DIRECT CONTACT							SURFACE SOIL/ FOODSTUFFS
	Resid./ Farmer	NG/ NG	Resid./ Farmer	Resid./ Farmer	Indust./ Worker	Resid./ Farmer	Rec./ Recreator	Indust./ Worker	Mod. Care./ Hunter-Trapper	Mod. Care./ Security Guard	NG/ Hunter-Trapper	NG/ NG	Resid./ Farmer
Inorganics													
Antimony													X
Arsenic						X		X				X	X
Barium													X
Cadmium				X		X						X	X
Chromium												X	X
Manganese	X												
Zinc													X
Organics													
1,3,5-Trinitrobenzene													X
2,4,6-Trinitrotoluene				X	X	X		X				X	X
Benzo(a)anthracene			X										X
Benzo(a)pyrene			X	X	X	X		X					X
Benzo(b)fluoranthene			X										X
Chloroform	X	X											
Dibenzo(a,h)anthracene				X		X							X
HMX													X
Indeno(1,2,3-cd)pyrene													X
RDX	X	X		X	X	X	X	X	X	X	X	X	X

[a] COCs = Chemicals of concern. Only land use/receptor/medium combinations with COCs are shown.

Land Use/Receptor Codes:

Resid./Farmer = Open Residential land use; on-site resident farmer as the receptor
NG/NG = National Guard/Managed Recreational land use; National Guard as the receptor
Indust./Worker = Open Industrial land use; Industrial Worker as the receptor
Rec./Recreator = Open Recreational land use; Recreator as the receptor
Mod. Care./Hunter-Trapper = Modified Caretaker/Managed Recreational land use; Hunter/Trapper as the receptor
Mod. Care./Security Guard = Modified Caretaker/Managed Recreational land use; Security Guard as the receptor
NG/Hunter-Trapper = National Guard/Managed Recreational land use; Hunter/Trapper as the receptor

Table 6-11. COCs with Large Risks/Hazards

Chemical of Concern	Groundwater Open Residential/ On-Site Residential Farmer	Surface Soil/ Direct Contact Open Residential/ On-Site Residential Farmer	Surface Soil/ Foodstuffs Open Residential/ On-Site Residential Farmer	Subsurface Soil Open Residential/ On-Site Residential Farmer
Inorganics				
Antimony			H (veg.)	
Arsenic			H (veg.), R (veg.)	
Barium			H (veg.)	
Cadmium		H (dermal)	H ($milk_{child}$, veg.)	H (dermal)
Chromium			H (veg.)	
Manganese	H (ingestion)			
Zinc			H (beef, $milk_{adult}$, $milk_{child}$, veg.)	
Organics				
TNB			H (veg.)	
TNT		H ($Ingestion_{child}$)	H (veg.), R (veg.)	H ($Ingestion_{child}$)
Benzo(*a*)pyrene			R (milk, veg.)	
Dibenzo(*a,h*)anthracene			R (beef, milk, veg.)	
HMX			H (veg.)	
Indeno(1,2,3-*cd*)pyrene[b]			R (beef, milk, veg.)	
RDX		H ($Ingestion_{child}$)	H (veg.), R (veg.)	

COC = Chemical of concern; H = hazard COC; R = risk COC; veg. = vegetable.

[a] COCs with large risks/hazards are COCs with a total hazard index > 1 or with a total risk > 10^{-4}; only COCs meeting these criteria and their significant pathways are shown here.

[b] Indeno(1,2,3-*cd*)pyrene is a COC with large risk for the on-site residential farmer receptor because its total risk is > 10^{-4}. Risks from individual pathways (ingestion of beef, milk, and vegetables) are actually < 10^{-4}, but the sum of the risks from these pathways is > 10^{-4}.

Table 6-12. Summary of Cancer Risks to Receptors Across Multiple Media

Receptor	Cancer Risks						
	Surface Soil/Direct[a]	Surface Soil/Indirect[b]	Subsurface Soil	Sediment	Surface Water[c]	Groundwater	Total
Security Guard/Maintenance Worker	6.9E-06	NE	NE	NE	NE	NE	6.9E-06
Hunter/Trapper	5.1E-06	2.0E-07	NE	1.0E-06	0.0E+00	NE	6.3E-06
Trespasser	1.9E-06	NE	NE	3.9E-07	0.0E+00	NE	2.3E-06
National Guard	2.6E-05	NE	8.8E-07	1.0E-06	0.0E+00	6.9E-06	3.5E-05
Recreator	4.0E-06	NE	NE	8.4E-07	0.0E+00	NE	4.8E-06
Industrial Worker	2.7E-05	NE	1.5E-05	NE	NE	NE	4.2E-05
Resident Farmer Adult	1.1E-04	1.1E-02	5.8E-05	9.8E-06	0.0E+00	2.3E-05	1.1E-02

NE = Not evaluated for this receptor.
[a]Risks are from direct contact with surface soil (i.e., via ingestion, dermal contact, and inhalation).
[b]Risks are from indirect contact with surface soil. For the hunter/trespasser, this is from ingestion of venison. For the resident farmer, this is from ingestion of beef, milk, and vegetables.
[c]There were no surface water COPCs; therefore, values of zero appear where surface water would have been evaluated.

Table 6-13. Summary of Noncancer Hazards to Receptors Across Multiple Media

Receptor	Noncancer Hazard Index						
	Surface Soil/Direct[a]	Surface Soil/Indirect[b]	Subsurface Soil	Sediment	Surface Water[c]	Groundwater	Total
Security Guard/Maintenance Worker	9.2E-01	NE	NE	NE	NE	NE	9.2E-01
Hunter/Trapper	5.6E-01	5.3E-02	NE	1.3E-02	0.0E+00	NE	6.3E-01
Trespasser	1.1E+00	NE	NE	2.4E-02	0.0E+00	NE	1.1E+00
National Guard	9.0E-01	NE	9.6E-02	3.2E-03	0.0E+00	5.3E-01	1.5E+00
Recreator	4.6E-01	NE	NE	1.0E-02	0.0E+00	NE	4.7E-01
Industrial Worker	1.4E+00	NE	1.1E+00	NE	NE	NE	2.5E+00
Resident Farmer Adult	2.8E+00	3.1E+02	2.2E+00	8.2E-02	0.0E+00	2.0E+00	3.2E+02
Resident Farmer Child[d]	6.7E+00	1.8E+01	4.7E+00	NE	0.0E+00	NE	2.9E+01

NE = Not evaluated for this receptor.
[a]Hazards are from direct contact with surface soil (i.e., via ingestion, dermal contact, and inhalation).
[b]Hazards are from indirect contact with surface soil. For the hunter/trespasser, this is from ingestion of venison. For the resident farmer, this is from ingestion of beef, milk, and vegetables.
[c]There were no surface water COPCs; therefore, values of zero appear where surface water would have been evaluated.
[d]The resident farmer child was evaluated only for the ingestion of soil and the ingestion of milk pathways.

6.5.2.2 Results of the Risk Point Estimates

This section presents the results of the risks and hazards estimated on a location-by-location basis. These results are used to further support the aggregate risk results (see Section 6.5.2.1) and are presented graphically in Appendix J (see **Figures J.1** through **J.23**). Since the assumption that a receptor remains in one location is unreasonable, this location-by-location evaluation is useful for focusing on the highest risk locations within the AOC. For this reason, the location-by-location risk/hazard results are presented graphically and should be used primarily to help locate priority areas within the AOC, not as the determining factor in the decision to implement a remedial action.

Note that summing risks or hazards across all individual locations should not be performed because the assumption for calculating each location's risk or hazard is that the receptor spends his/her entire exposure duration at that location. For example, for the on-site resident farmer exposed to surface soil, the assumption would be that this receptor is exposed to the surface soil at that location for 350 days/year for 30 years. To then sum risks or hazards across all surface soil locations across the AOC (each calculated with the same exposure parameters) is unrealistic and is not advised.

Each figure contains location-by-location total chemical risks and/or total chemical hazards for a given receptor and medium. The risk/hazard has been calculated at each location, using the maximum detected concentration as the EPC at that location. Risks for all carcinogenic COPCs have been summed for each location and plotted on the figures; similarly, HQs for all noncarcinogenic COPCs have been summed for each location and plotted on the figures. Each figure has categorized the risks/hazard into one of four categories, based on the calculated total risk/hazard for that location. These four categories are:

- Sampled, but no risk/hazard calculated. These are locations across WBG for which samples have been collected, but no quantitative COPCs (COPCs with toxicity values) exist for the location, due to the screening process in determining COPCs (see Sections 6.2.1 – 6.2.3 for detailed information on the determination of SRCs and, subsequently, COPCs). Reasons for not having quantitative COPCs at a specific location include:

1. analytes with all non-detected concentrations or a high percentage (at least 95 percent) of non-detected concentrations;

2. metals detected below background have been eliminated from the COPC list;

3. essential human nutrients have been eliminated from the COPC list;

4. analytes detected below RBSCs (or any other screening level employed, such as MCLs for groundwater) have been eliminated from the COPC list;

5. analytes that remain on the COPC list after all above screens might not have valid toxicity values (e.g., RfD or cancer slope factor).

If all analytes are eliminated for one of these reasons, then no calculation of risk/hazard is made because there are no quantitative COPCs. Consequently a grey circle is plotted for all such locations.

- Chemical risk < 10^{-6} or chemical hazard < 1.0. This category is established as the "low level" category. All risks/hazards falling into this category are indicated with a green circle on the figures.

- Chemical risk between 10^{-6} and 10^{-4} or chemical hazards between 1 and 3. This category is established as the "middle level" category. All risks/hazards falling into this middle category are indicated with a yellow circle on the figures.

- Chemical risk $\geq 10^{-4}$ or chemical hazard ≥ 3.0. This category is established as the "high level" category in order to help focus on a relatively small number of locations that have large risk/hazard levels. All risks/hazards falling into this high level category are indicated with a red circle on the figures.

The following sections discuss the results of the location-by-location risk evaluation for each medium. All locations where the total chemical risk is $\geq 10^{-6}$ and all locations where the HI is ≥ 1.0 will be listed in these Sections, with a special indicator (an asterisk) applied to those locations where the total chemical risk is $\geq 10^{-4}$ and for all locations where the HI is ≥ 3.0. These location-by-location results will be tied to the aggregate risk results (which are presented in Section 6.5.2.1).

6.5.2.2.1 Groundwater location-by-location risks

Two receptors (National Guard and on-site resident farmer) have been evaluated for groundwater. Recall from Section 6.5.2.1.1 that chloroform and RDX are COCs with cancer risks between 10^{-6} and 10^{-4} for both the National Guard and on-site resident farmer. Also recall that manganese is a COC with cancer risk $\geq 10^{-4}$ and/or hazard ≥ 1.0 for the on-site resident farmer.

Figure J.1 presents the well-by-well groundwater cancer risks across WBG for the two receptors. Groundwater chemical risks exceed 10^{-6} (but are $< 10^{-4}$) for both the National Guard and the on-site resident farmer at the following sampling stations (with the nearest pad location designated within the parentheses:

- WBGmw-005 (near Pad #62)
- WBGmw-006 (near Pad #67)
- WBGmw-008 (near Pad #25)
- WBGmw-009 (near Pad #7)

Figure J.2 presents the well-by-well groundwater hazards across WBG for the two receptors. As seen only one location, WBGmw-008 (near Pad #25), has a total hazard between 1 and 3 for the on-site resident farmer (from manganese). As expected, all locations for the National Guard receptor have groundwater hazards < 1.

6.5.2.2.2 Surface Water location-by-location risks

There are no risks or hazards calculated for surface water on a location-by-location basis since there are no COPCs for surface water (see **Table J.2.2**).

6.5.2.2.3 Sediment location-by-location risks

Five receptors (child trespasser, hunter/trapper, National Guard, recreator, and on-site resident farmer) have been evaluated for exposure to sediment at WBG. Recall from Section 6.5.2.1.3 that benzo(*a*)anthracene, benzo(*a*)pyrene, and benzo(*b*)fluoranthene are carcinogenic COCs with cancer risks between 10^{-6} and 10^{-4} for the on-site resident farmer.

Figure J.3 presents the location-by-location cancer risks across WBG for the child trespasser and hunter/trapper under the Modified Caretaker/Managed Recreational land use. As expected (based on the results of the aggregated risks), most locations show a total cancer risk $< 10^{-6}$ for these two receptors. The one exception is for location WBGsd-0156 (near Pad #70) for the hunter/trapper, where the total cancer risk

across all chemicals is 1.0E-06; however, no exceedances of 10^{-6} for individual chemicals are found at this location for this receptor.

Figure J.4 presents the location-by-location hazards across WBG for the child trespasser and hunter/trapper under the Modified Caretaker/Managed Recreational land use. As expected (based on the results of the aggregated hazards), all locations where hazards are calculated produce values < 1.0 for both receptors.

Figure J.5 presents the location-by-location cancer risks across WBG for the child trespasser, hunter/trapper, and National Guard under the National Guard /Managed Recreational land use. As expected (based on the results of the aggregated risks), most locations show a total cancer risk < 10^{-6} for these three receptors. The one exception is for location WBGsd-0156 (near Pad #70) for the hunter/trapper, where the total cancer risk across all chemicals is 1.0E-06; however, no exceedances of 10^{-6} for individual chemicals are found at this location for this receptor.

Figure J.6 presents the location-by-location hazards across WBG for the child trespasser, hunter/trapper, and National Guard under the National Guard /Managed Recreational land use. As expected (based on the results of the aggregated hazards), all locations where hazards are calculated produce values < 1.0 for all three receptors.

Figure J.7 presents the location-by-location risks and hazards across WBG for the recreator (under the Open Recreational land use). Displaying consistency with the aggregated risk/hazard results, there are no locations with risks $\geq$ 10^{-6} or with hazards $\geq$ 1.0 for the recreator exposed to sediment.

Figure J.8 presents the location-by-location risks and hazards across WBG for the on-site resident farmer (under the Open Residential land use). As expected (based on the results of the aggregated hazards) there are no locations with a total chemical hazard $\geq$ 1.0. Since the aggregated risk results produced three carcinogenic COCs, it is not surprising that there is a single location whose total risk is $\geq$ 10^{-6}. The total cancer risk for location WBGsd-0156 (near Pad #70) is the location with a total risk between 10^{-6} and 10^{-4}. After reviewing the aggregated risks (see **Table 6-6**), it is evident that location WBGsd-0156 is the location responsible for the three sediment COCs (which are PAHs) for the on-site resident farmer (since all three COCs have a frequency of detection of 1/3 and their EPCs are based on the maximum detected concentration).

Figure J.9 presents a summary of sediment risks on a location-by-location basis for the National Guard, recreator, and on-site resident farmer receptors. The information displayed on this figure has been previously displayed on separate figures (see cancer risks displayed for these receptors on **Figures J.5, J.7**, and **J.8**, respectively). **Figure J.9** displays these risks on the same page, for ease of comparison between these receptors. As mentioned above, there is one location (WBGsd-0156, near Pad #70) for the on-site resident farmer that has a total chemical risk between 10^{-6} and 10^{-4}. All other locations have sediment risks < 10^{-6} for these three receptors.

Figure J.10 presents a summary of sediment hazards on a location-by-location basis for the National Guard, recreator, and on-site resident farmer receptors. The information displayed on this figure has been previously displayed on separate figures (see hazards displayed for these receptors on **Figures J.6, J.7,** and **J.8**, respectively). **Figure J.10** displays these hazards on the same page, for ease of comparison between these receptors. As discussed above and as seen from this figure, all calculated location-by-location hazards are < 1.0 for all three of these receptors.

6.5.2.2.4 Subsurface soil location-by-location risks

Three receptors (National Guard, industrial worker, and on-site resident farmer) have been evaluated for exposure to subsurface soil at WBG. Recall from the subsurface soil aggregated risks/hazards (see Section 6.5.2.1.6) that:

- no COCs are identified for the National Guard;
- three carcinogenic COCs are identified for the industrial worker (TNT, benzo(*a*)pyrene, and RDX); and
- five COCs are identified for the on-site resident farmer (cadmium, TNT, benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX). Two of the five are noncarcinogenic COCs, while four of the five are carcinogenic COCs. The two noncarcinogenic COCs are cadmium and TNT. The four carcinogenic COCs are TNT, benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX.

Figure J.11 presents the subsurface soil location-by-location cancer risks across WBG for the National Guard, industrial worker, and on-site resident farmer receptors. Location-by-location risks for each receptor are discussed below.

National Guard subsurface soil risks. Since the aggregated risk results for the National Guard produced no COCs, one might expect no locations to have a total risk < 10^{-6}. However, when determining the EPC for an aggregated risk evaluation, the EPC is often based on the UCL_{95} on the mean concentration rather than on the maximum detected concentration when sample sizes are large. This is logical since the UCL_{95} on the mean is a statistic about the center of the data distribution, while the maximum detected concentration is, of course, representative of the upper tail of the data distribution. With large data sets (such as for this subsurface soil data set, with 130 sample results for TNT and RDX), the UCL_{95} on the mean should be closer to the center of the data distribution than to the upper tail of the distribution. Indeed, as seen from **Table 6-9**, the maximum detected concentrations for TNT and RDX are an order of magnitude larger than their respective UCL_{95} on the mean concentrations. Consequently, using the same risk parameters, one would expect the risks calculated using these two concentrations (i.e., the UCL_{95} on the mean and the maximum detected concentration) to differ by an order of magnitude.

The risks from the aggregated subsurface soil data for TNT and RDX (using the UCL_{95} on the mean concentrations as the EPCs) are between 10^{-7} and 10^{-6}. Therefore, it is not surprising that concentrations at or near the maximum detected value for these two chemicals produce risk values > 10^{-6}. As seen on **Figure J.11**, there are two locations where the total chemical risks for the National Guard exposed to subsurface soil fall between 10^{-6} and 10^{-4}. Those locations are listed below (with the nearest pad listed within the parentheses):

- WBGso-069 (near Pad #66)
- WBGso-070 (near Pad #67).

Industrial worker subsurface soil risks. As expected (based on the results of the aggregated risks, which produced three carcinogenic COCs), some locations show a total cancer risk $\geq$ 10^{-6} for the industrial worker; refer to **Figure J.11**. The following locations produced subsurface soil risks $\geq$ 10^{-6}, with one location (marked with an asterisk) resulting in a total chemical risk $\geq$ 10^{-4}:

- WBGso-062 (near Pad #62)
- WBGso-069 (near Pad #66)
- WBGso-070 (near Pad #67) *
- WBGso-140 (near Pad #67)

- WBGso-186 (near Pad #67)
- WBGss-131 (near Pad #66)
- WBGss-168 (near Pad #66)
- WBGss-190 (near Pad #70)
- WBGss-191 (near Pad #70).

On-site resident farmer subsurface soil risks. As expected (based on the results of the aggregated risks, which produced three carcinogenic COCs), some locations show a total cancer risk $\geq 10^{-6}$ for the industrial worker; refer to **Figure J.11**. The following locations produced subsurface soil risks $\geq 10^{-6}$, with two locations (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGso-055 (near Pad #59)
- WBGso-062 (near Pad #62)
- WBGso-069 (near Pad #66) *
- WBGso-070 (near Pad #67) *
- WBGso-122 (near Pad #60)
- WBGso-140 (near Pad #67)
- WBGso-142 (near Pad #68)
- WBGso-186 (near Pad #67)
- WBGss-033 (near Pad #37)
- WBGss-114 (near Pad #58)
- WBGss-131 (near Pad #66)
- WBGss-168 (near Pad #66)
- WBGss-190 (near Pad #70)
- WBGss-191 (near Pad #70).

Figure J.12 presents the subsurface soil location-by-location hazards across WBG for the National Guard, industrial worker, and on-site resident farmer receptors. Location-by-location hazards for each of these receptors are discussed below.

National Guard subsurface soil hazards. As discussed above for risks, there are large differences between the UCL_{95} on the mean concentrations and the maximum detected concentration for some chemicals in the subsurface soil. This is the case for cadmium (UCL_{95} on the mean concentration is 17.9 mg/kg and its maximum detected concentration is 877 mg/kg; see **Table 6-9**). Since the EPC used in the aggregated risk is 17.9 mg/kg and this EPC produces an HI of 0.06, it is not surprising that the HI as calculated from the maximum detected concentration (877 mg/kg) is larger than 1.0. The one location with a large total chemical hazard that is shown on Figure J.12 for the National Guard is from WBGss-034 (near Pad #38). Since its total hazard (across all chemicals) is > 3.0, this location is depicted with a red circle on **Figure J.12**. All other locations produced hazards < 1.0 for the National Guard exposed to subsurface soil.

Industrial worker subsurface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the industrial worker exposed to subsurface soil, the great difference between the UCL_{95} on the mean concentrations and the maximum detected concentration comes into play for some chemicals. Consequently, there are some locations that produce hazards ≥ 1.0 (and a few that produce hazards ≥ 3.0) for this receptor. The following locations produced subsurface soil hazards ≥ 1.0, with four locations (marked with an asterisk) resulting in a total hazard ≥ 3:

- WBGso-035 (near Pad #38)
- WBGso-059 (near Pad #61)

- WBGso-069 (near Pad #66) *
- WBGso-070 (near Pad #67) *
- WBGso-122 (near Pad #60)
- WBGss-034 (near Pad #38) *
- WBGss-114 (near Pad #58)
- WBGss-146 (near Pad #45) *
- WBGss-168 (near Pad #66).

On-site resident farmer subsurface soil hazards. As expected (based on the results of the aggregated risks, which produced two noncarcinogenic COCs), some locations show a total hazard $\geq$ 1.0 for the on-site resident farmer; refer to **Figure J.12**. The following locations produced subsurface soil hazards $\geq$ 1.0, with eight locations (marked with an asterisk) resulting in a total hazard $\geq$ 3:

- WBGso-035 (near Pad #38) *
- WBGso-057 (near Pad #60)
- WBGso-059 (near Pad #61) *
- WBGso-069 (near Pad #66) *
- WBGso-070 (near Pad #67) *
- WBGso-107 (near Pad #37)
- WBGso-122 (near Pad #60) *
- WBGss-032 (near Pad #37)
- WBGss-034 (near Pad #38) *
- WBGss-114 (near Pad #58) *
- WBGss-120 (near Pad #60)
- WBGss-126 (near Pad #61)
- WBGss-146 (near Pad #45) *
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58).

6.5.2.2.5 Location-by-location risks for direct exposure to surface soil

Seven receptors (child trespasser, hunter/trapper, security guard/maintenance worker, National Guard, industrial worker, recreator, and on-site resident farmer) have been evaluated for direct exposure to surface soil at WBG. Recall from the soil aggregated risks/hazards for the direct contact with surface soil (see Section 6.5.2.1.4) that:

- no COCs are identified for the child trespasser;

- one carcinogenic COC is identified for the hunter/trapper (RDX);

- one carcinogenic COC is identified for the security guard/maintenance worker (RDX);

- five carcinogenic COCs are identified for the National Guard (arsenic, cadmium, chromium, TNT, and RDX);

- four carcinogenic COCs are identified for the industrial worker [arsenic, TNT, benzo(*a*)pyrene, and RDX];

- one carcinogenic COC is identified for the recreator (RDX); and

- six COCs are identified for the on-site resident farmer. Three of the six are noncarcinogenic COCs, while five of the six are carcinogenic COCs. The three noncarcinogenic COCs are cadmium, TNT, and RDX. The five carcinogenic COCs are arsenic, TNT, benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX.

Various figures are shown in Appendix J, depicting location-by-location risks and hazards to the receptors from direct exposure to surface soil across the WBG. These risks and hazards are discussed below.

Figure J.13 displays cancer risks from direct exposure to surface soils on a location-by-location basis for the three receptors evaluated within the Modified Caretaker/Managed Recreational land use: the security guard/maintenance worker, the hunter/trapper, and the child trespasser. A discussion of location-by-location risks to each of these receptors follows.

Security guard/maintenance worker direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced one carcinogenic COC), some locations show a total cancer risk $\geq 10^{-6}$ for the security guard/maintenance worker exposed directly to the surface soil. As seen from **Figure J.13**, the following locations produced risks $\geq 10^{-6}$, with one location (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGss-003 (near Pad #3)
- WBGss-004 (near Pad #4)
- WBGss-005 (near Pad #5)
- WBGss-006 (near Pad #6)
- WBGss-008 (near Pad #8)
- WBGss-023 (near Pad #30)
- WBGss-024 (between Pad #30 and Pad #32)
- WBGss-026 (near Pad #33)
- WBGss-030 (near Pad #37)
- WBGss-037 (near Pad #40)
- WBGss-038 (near Pad #41)
- WBGss-042 (near Pad #46)
- WBGss-045 (near Pad #49)
- WBGss-046 (near Pad #50)
- WBGss-054 (near Pad #58)
- WBGss-062 (near Pad #62)
- WBGss-067 (near Pad #65)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67) *
- WBGss-108 (near Pad #38)
- WBGss-111 (near Pad #40)
- WBGss-112 (near Pad #40)
- WBGss-114 (near Pad #58)
- WBGss-116 (near Pad #58)
- WBGss-131 (near Pad #66)
- WBGss-144 (between Pad #45 and Pad #60)
- WBGss-147 (near Pad #45)
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58)
- WBGss-177 (near Pad #68)

- WBGss-179 (near Pad #67)
- WBGss-191 (near Pad #70).

Hunter/trapper direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced one carcinogenic COC), some locations show a total cancer risk $\geq 10^{-6}$ for the hunter/trapper exposed directly to the surface soil. As seen from **Figure J.13**, the following locations produced risks $\geq 10^{-6}$, with one location (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGss-004 (near Pad #4)
- WBGss-038 (near Pad #41)
- WBGss-062 (near Pad #62)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67) *
- WBGss-112 (near Pad #40)
- WBGss-131 (near Pad #66)
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58)
- WBGss-177 (near Pad #68)
- WBGss-191 (near Pad #70).

Child trespasser direct exposure to surface soil risks. Although the aggregated risk evaluation produced no carcinogenic COCs for the child trespasser exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in risks $\geq 10^{-6}$ for some locations. See **Table 6-7** for the differences in these two summary statistics for TNT and RDX. As seen from **Figure J.13**, the following locations produced surface soil risks between 10^{-6} and 10^{-4} for the child trespasser:

- WBGss-062 (near Pad #62)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67)
- WBGss-168 (near Pad #66).

Figure J.14 displays hazards from direct exposure to surface soils on a location-by-location basis for the three receptors evaluated within the Modified Caretaker/Managed Recreational land use: the security guard/maintenance worker, the hunter/trapper, and the child trespasser. A discussion of location-by-location hazards for each of these receptors follows.

Security guard/maintenance worker direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the security guard/maintenance worker exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards ≥ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.14**, the following locations produced surface soil hazards ≥ 1.0, with four locations (marked with an asterisk) resulting in a total hazard ≥ 3 for the security guard/maintenance worker:

- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38)
- WBGss-059 (near Pad #61)
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-114 (near Pad #58)

- WBGss-122 (near Pad #60)
- WBGss-146 (near Pad #45). *

Hunter/trapper direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the hunter/trapper exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards $\geq$ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.14**, the following locations produced surface soil hazards $\geq$ 1.0, with three locations (marked with an asterisk) resulting in a total hazard $\geq$ 3 for the hunter/trapper:

- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67) *
- WBGss-114 (near Pad #58)
- WBGss-146 (near Pad #45) *.

Child trespasser direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the child trespasser exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards $\geq$ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.14**, the following locations produced surface soil hazards $\geq$ 1.0, with four locations (marked with an asterisk) resulting in a total hazard $\geq$ 3 for the child trespasser:

- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38)
- WBGss-059 (near Pad #61)
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-114 (near Pad #58)
- WBGss-122 (near Pad #60)
- WBGss-146 (near Pad #45) *.

Figure J.15 displays cancer risks from direct exposure to surface soils on a location-by-location basis for the three receptors evaluated within the National Guard/Managed Recreational land use: the National Guard, the hunter/trapper, and the child trespasser. Note that since the child trespasser and the hunter/trapper are the same receptors under the Modified Caretaker/Managed Recreational land use and the National Guard/Managed Recreational land use, their cancer risks are identical for these two land uses. Consequently, the risks for the child trespasser displayed in **Figures J.13** and **J.15** are identical; the risks for the hunter trapper displayed in **Figures J.13** and **J.15** are identical. Therefore, the discussion of these two receptors are not repeated for the National Guard/Managed Recreational land use. A discussion of location-by-location risks for the National Guard receptor follows.

National Guard direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced five carcinogenic COCs), some locations show a total cancer risk $\geq 10^{-6}$ for the National Guard exposed directly to the surface soil. As seen from **Figure J.15**, the following locations produced risks $\geq 10^{-6}$, with one location (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGss-003 (near Pad #3)
- WBGss-004 (near Pad #4)

- WBGss-005 (near Pad #5)
- WBGss-006 (near Pad #6)
- WBGss-008 (near Pad #8)
- WBGss-022 (near Pad #29)
- WBGss-023 (near Pad #30)
- WBGss-024 (between Pad #30 and Pad #32)
- WBGss-026 (near Pad #33)
- WBGss-027 (near Pad #34)
- WBGss-030 (near Pad #37)
- WBGss-032 (near Pad #37)
- WBGss-034 (near Pad #38)
- WBGss-035 (near Pad #38)
- WBGss-037 (near Pad #40)
- WBGss-038 (near Pad #41)
- WBGss-042 (near Pad #46)
- WBGss-045 (near Pad #49)
- WBGss-046 (near Pad #50)
- WBGss-047 (near Pad #51)
- WBGss-054 (near Pad #58)
- WBGss-055 (near Pad #59)
- WBGss-057 (near Pad #60)
- WBGss-058 (near Pad #60)
- WBGss-059 (near Pad #61)
- WBGss-062 (near Pad #62)
- WBGss-063 (near Pad #63)
- WBGss-064 (near Pad #63)
- WBGss-067 (near Pad #65)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67) *
- WBGss-071 (near Pad #67)
- WBGss-073 (near Pad #68)
- WBGss-106 (near Pad #37)
- WBGss-107 (near Pad #37)
- WBGss-108 (near Pad #38)
- WBGss-109 (near Pad #38)
- WBGss-111 (near Pad #40)
- WBGss-112 (near Pad #40)
- WBGss-114 (near Pad #58)
- WBGss-115 (near Pad #58)
- WBGss-116 (near Pad #58)
- WBGss-118 (near Pad #59)
- WBGss-120 (near Pad #60)
- WBGss-121 (near Pad #60)
- WBGss-122 (near Pad #60)
- WBGss-126 (near Pad #61)
- WBGss-128 (near Pad #62)
- WBGss-129 (near Pad #62)
- WBGss-131 (near Pad #66)

- WBGss-132 (near Pad #66)
- WBGss-134 (near Pad #66)
- WBGss-136 (near Pad #67)
- WBGss-140 (near Pad #67)
- WBGss-141 (near Pad #68)
- WBGss-142 (near Pad #68)
- WBGss-144 (between Pad #45 and Pad #60)
- WBGss-145 (between Pad #45 and Pad #60)
- WBGss-146 (near Pad #45)
- WBGss-147 (near Pad #45)
- WBGss-148 (near Pad #45)
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58)
- WBGss-171 (near Pad #58)
- WBGss-172 (near Pad #59)
- WBGss-174 (near Pad #60)
- WBGss-175 (near Pad #37)
- WBGss-177 (near Pad #68)
- WBGss-178 (near Pad #67)
- WBGss-179 (near Pad #67)
- WBGss-187 (near Pad #37)
- WBGss-188 (near Pad #70)
- WBGss-189 (near Pad #70)
- WBGss-191 (near Pad #70)
- WBGss-193 (near Pad #62)
- WBGss-194 (near Pad #62).

Figure J.16 displays hazards from direct exposure to surface soils on a location-by-location basis for the three receptors evaluated within the National Guard/Managed Recreational land use: the National Guard, the hunter/trapper, and the child trespasser. Note that since the child trespasser and the hunter/trapper are the same receptors under the Modified Caretaker/Managed Recreational land use and the National Guard/Managed Recreational land use, their hazards are identical for these two land uses. Consequently, the hazards for the child trespasser displayed in **Figures J.14** and **J.16** are identical; the hazards for the hunter trapper displayed in **Figures J.14** and **J.16** are identical. Therefore, the discussion of these two receptors are not repeated for the National Guard/Managed Recreational land use. A discussion of location-by-location hazards for the National Guard receptor follows.

National Guard direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the National Guard exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards $\geq$ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.16**, the following locations produced surface soil hazards $\geq$ 1.0, with four locations (marked with an asterisk) resulting in a total hazard $\geq$ 3 for the National Guard:

- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38)
- WBGss-059 (near Pad #61)
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *

- WBGss-114 (near Pad #58)
- WBGss-122 (near Pad #60)
- WBGss-141 (near Pad #68)
- WBGss-142 (near Pad #68)
- WBGss-146 (near Pad #45) *
- WBGss-177 (near Pad #68).

Figure J.17 displays risks and hazards from direct exposure to surface soils on a location-by-location basis for the industrial worker evaluated within the Open Industrial land use. A discussion of these risks and hazards follows.

Industrial worker direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced four carcinogenic COCs), some locations show a total cancer risk $\geq 10^{-6}$ for the industrial worker exposed directly to the surface soil. As seen from **Figure J.17**, the following locations produced cancer risks $\geq 10^{-6}$, with one location (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGss-003 (near Pad #3)
- WBGss-004 (near Pad #4)
- WBGss-005 (near Pad #5)
- WBGss-006 (near Pad #6)
- WBGss-008 (near Pad #8)
- WBGss-023 (near Pad #30)
- WBGss-024 (between Pad #30 and Pad #32)
- WBGss-026 (near Pad #33)
- WBGss-030 (near Pad #37)
- WBGss-037 (near Pad #40)
- WBGss-038 (near Pad #41)
- WBGss-042 (near Pad #46)
- WBGss-045 (near Pad #49)
- WBGss-046 (near Pad #50)
- WBGss-047 (near Pad #51)
- WBGss-054 (near Pad #58)
- WBGss-062 (near Pad #62)
- WBGss-067 (near Pad #65)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67) *
- WBGss-071 (near Pad #67)
- WBGss-108 (near Pad #38)
- WBGss-111 (near Pad #40)
- WBGss-112 (near Pad #40)
- WBGss-114 (near Pad #58)
- WBGss-116 (near Pad #58)
- WBGss-131 (near Pad #66)
- WBGss-140 (near Pad #67)
- WBGss-144 (between Pad #45 and Pad #60)
- WBGss-145 (between Pad #45 and Pad #60)
- WBGss-147 (near Pad #45)

- WBGss-148 (near Pad #45)
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58)
- WBGss-177 (near Pad #68)
- WBGss-179 (near Pad #67)
- WBGss-190 (near Pad #70)
- WBGss-191 (near Pad #70).

Industrial worker direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the industrial worker exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards $\geq$ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.17**, the following locations produced surface soil hazards $\geq$ 1.0, with four locations (marked with an asterisk) resulting in a total hazard $\geq$ 3 for the industrial worker:

- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38)
- WBGss-059 (near Pad #61)
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-114 (near Pad #58)
- WBGss-122 (near Pad #60)
- WBGss-146 (near Pad #45) *
- WBGss-168 (near Pad #66).

Figure J.18 displays risks and hazards from direct exposure to surface soils on a location-by-location basis for the recreator evaluated within the Open Recreational land use. A discussion of these risks and hazards follows.

Recreator direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced one minor carcinogenic COC), some locations show a total cancer risk $\geq 10^{-6}$ for the recreator exposed directly to the surface soil. As seen from **Figure J.18**, the following locations produced cancer risks between 10^{-6} and 10^{-4}:

- WBGss-062 (near Pad #62)
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67)
- WBGss-112 (near Pad #40)
- WBGss-131 (near Pad #66)
- WBGss-168 (near Pad #66)
- WBGss-191 (near Pad #70).

Recreator direct exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the recreator exposed directly to surface soil, the great difference between the UCL_{95} on the mean concentrations results in hazards $\geq$ 1.0 for some locations. See **Table 6-7** for the differences in these two summary statistics for cadmium, TNT and RDX. As seen from **Figure J.18**, the following locations produced surface soil hazards $\geq$ 1.0, with two locations (marked with an asterisk) resulting in a total hazard $\geq$ 3 for the recreator:

- WBGss-034 (near Pad #38) *
- WBGss-069 (near Pad #66)
- WBGss-070 (near Pad #67)
- WBGss-114 (near Pad #58)
- WBGss-146 (near Pad #45). *

Figure J.19 displays risks and hazards from direct exposure to surface soils on a location-by-location basis for the on-site resident farmer evaluated within the Open Residential land use. A discussion of these risks and hazards follows.

On-site resident farmer direct exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced five carcinogenic COCs), some locations show a total cancer risk $\geq 10^{-6}$ for the on-site resident farmer exposed directly to the surface soil. As seen from **Figure J.19**, the following locations produced cancer risks $\geq 10^{-6}$, with two locations (marked with an asterisk) resulting in a total chemical risk $\geq 10^{-4}$:

- WBGss-003 (near Pad #3)
- WBGss-004 (near Pad #4)
- WBGss-005 (near Pad #5)
- WBGss-006 (near Pad #6)
- WBGss-008 (near Pad #8)
- WBGss-023 (near Pad #30)
- WBGss-024 (between Pad #30 and Pad #32)
- WBGss-026 (near Pad #33)
- WBGss-030 (near Pad #37)
- WBGss-033 (near Pad #37)
- WBGss-037 (near Pad #40)
- WBGss-038 (near Pad #41)
- WBGss-042 (near Pad #46)
- WBGss-045 (near Pad #49)
- WBGss-046 (near Pad #50)
- WBGss-047 (near Pad #51)
- WBGss-054 (near Pad #58)
- WBGss-055 (near Pad #59)
- WBGss-062 (near Pad #62)
- WBGss-067 (near Pad #65)
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-071 (near Pad #67)
- WBGss-108 (near Pad #38)
- WBGss-111 (near Pad #40)
- WBGss-112 (near Pad #40)
- WBGss-114 (near Pad #58)
- WBGss-116 (near Pad #58)
- WBGss-122 (near Pad #60)
- WBGss-131 (near Pad #66)
- WBGss-140 (near Pad #67)
- WBGss-142 (near Pad #68)

- WBGss-144 (between Pad #45 and Pad #60)
- WBGss-145 (between Pad #45 and Pad #60)
- WBGss-147 (near Pad #45)
- WBGss-148 (near Pad #45)
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58)
- WBGss-177 (near Pad #68)
- WBGss-179 (near Pad #67)
- WBGss-190 (near Pad #70)
- WBGss-191 (near Pad #70).

On-site resident farmer direct exposure to surface soil hazards. As expected (based on the results of the aggregated risk evaluation, which produced three noncarcinogenic COCs), some locations show a total chemical hazard $\geq$ 1.0 for the on-site resident farmer exposed directly to the surface soil. As seen from **Figure J.19**, the following locations produced total chemical hazards $\geq$ 1.0, with eight locations (marked with an asterisk) resulting in a total chemical hazard $\geq$ 3.0:

- WBGss-032 (near Pad #37)
- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38) *
- WBGss-057 (near Pad #60)
- WBGss-059 (near Pad #61) *
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-107 (near Pad #37)
- WBGss-114 (near Pad #58) *
- WBGss-120 (near Pad #60)
- WBGss-122 (near Pad #60) *
- WBGss-126 (near Pad #61)
- WBGss-146 (near Pad #45) *
- WBGss-168 (near Pad #66)
- WBGss-170 (near Pad #58).

Figure J.20 presents a summary of risks from direct contact with surface soil on a location-by-location basis for the National Guard, industrial worker, recreator, and on-site resident farmer receptors. The information displayed on this figure has been previously displayed on separate figures (see cancer risks displayed for these receptors on **Figures J.15, J.17, J.18**, and **J.19**, respectively). **Figure J.20** displays these risks on the same page, for ease of comparison between these receptors. As seen there are several locations with a total chemical risk between 10^{-6} and 10^{-4} and some locations with total chemical risk > 10^{-4}.

Figure J.21 presents a summary of sediment hazards on a location-by-location basis for the National Guard, industrial worker, recreator, and on-site resident farmer receptors. The information displayed on this figure has been previously displayed on separate figures (see hazards displayed for these receptors on **Figures J.16, J.17, J.18**, and **J.19**, respectively). Figure J.21 displays these hazards on the same page, for ease of comparison between these receptors. As discussed above and as seen from this figure, several locations had hazards $\geq$ 1.0 for all four of these receptors.

6.5.2.2.6 Location-by-location risks for indirect exposure to surface soil

Two receptors (hunter/trapper and on-site resident farmer) have been evaluated for indirect exposure to surface soil at WBG. This exposure includes the ingestion of foodstuffs such as venison, beef, milk, and vegetables, based on the concentrations found in the surface soil. Recall from the soil aggregated risks/hazards for the indirect contact with surface soil (see Section 6.5.2.1.5) that:

- no COCs are identified for the hunter/trapper, who is evaluated for the ingestion of venison only; and

- fifteen COCs are identified for the on-site resident farmer, who was evaluated for the ingestion of venison, beef, milk, and vegetables. Ten of the fifteen are noncarcinogenic COCs, while eight of the fifteen are carcinogenic COCs. The ten noncarcinogenic COCs are antimony, arsenic, barium, cadmium, chromium, zinc, TNB, TNT, HMX, and RDX. The eight carcinogenic COCs are arsenic, TNT, benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, dibenzo(*a,h*)anthracene, indeno(1,2,3-*cd*)pyrene, and RDX.

Two figures are shown in Appendix J, depicting location-by-location risks and hazards to the receptors across the WBG from indirect exposure to surface soil, via ingestion of foodstuffs. These risks and hazards are discussed below.

Figure J.22 displays cancer risks from indirect exposure to surface soils on a location-by-location basis for the hunter/trapper and the on-site resident farmer. A discussion of location-by-location risks to each of these receptors follows.

Hunter/trapper indirect exposure to surface soil risks. Note that since the hunter/trapper is the same receptor under the Modified Caretaker/Managed Recreational land use and the National Guard/Managed Recreational land use, the cancer risks are identical for this receptor in these two land uses. Therefore, in **Figure J.22**, the two maps showing the hunter/trapper's risks (for the two land uses) are identical. As expected (based on the results of the aggregated risks), all locations where risks are calculated produce values $< 10^{-6}$ for the hunter/trapper consuming venison.

On-site resident farmer indirect exposure to surface soil risks. As expected (based on the results of the aggregated risks, which produced eight carcinogenic COCs), some locations show a total cancer risk $\geq 10^{-6}$ for the on-site resident farmer exposed indirectly to the surface soil. As seen from **Figure J.22**, the following locations produced cancer risks $\geq 10^{-6}$, with most of these locations (marked with an asterisk) producing risks $\geq 10^{-4}$:

- WBGss-003 (near Pad #3) *
- WBGss-004 (near Pad #4) *
- WBGss-005 (near Pad #5) *
- WBGss-006 (near Pad #6) *
- WBGss-008 (near Pad #8) *
- WBGss-023 (near Pad #30) *
- WBGss-024 (between Pad #30 and Pad #32) *
- WBGss-026 (near Pad #33) *
- WBGss-030 (near Pad #37) *
- WBGss-033 (near Pad #37) *
- WBGss-035 (near Pad #38)
- WBGss-037 (near Pad #40) *
- WBGss-038 (near Pad #41) *

- WBGss-042 (near Pad #46) *
- WBGss-045 (near Pad #49) *
- WBGss-046 (near Pad #50) *
- WBGss-047 (near Pad #51) *
- WBGss-054 (near Pad #58) *
- WBGss-055 (near Pad #59) *
- WBGss-062 (near Pad #62) *
- WBGss-067 (near Pad #65) *
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-071 (near Pad #67) *
- WBGss-107 (near Pad #37)
- WBGss-108 (near Pad #38) *
- WBGss-111 (near Pad #40) *
- WBGss-112 (near Pad #40) *
- WBGss-114 (near Pad #58) *
- WBGss-116 (near Pad #58) *
- WBGss-122 (near Pad #60) *
- WBGss-131 (near Pad #66) *
- WBGss-140 (near Pad #67) *
- WBGss-141 (near Pad #68)
- WBGss-142 (near Pad #68) *
- WBGss-144 (between Pad #45 and Pad #60) *
- WBGss-145 (between Pad #45 and Pad #60) *
- WBGss-147 (near Pad #45) *
- WBGss-148 (near Pad #45) *
- WBGss-168 (near Pad #66) *
- WBGss-170 (near Pad #58) *
- WBGss-177 (near Pad #68) *
- WBGss-178 (near Pad #67)
- WBGss-179 (near Pad #67) *
- WBGss-187 (near Pad #37)
- WBGss-190 (near Pad #70) *
- WBGss-191 (near Pad #70) *.

Figure J.23 displays hazards from indirect exposure to surface soils on a location-by-location basis for the hunter/trapper and the on-site resident farmer. A discussion of location-by-location risks to each of these receptors follows.

Hunter/trapper indirect exposure to surface soil hazards. Although the aggregated risk evaluation produced no noncarcinogenic COCs for the hunter/trapper exposed indirectly to surface soil, the great difference between the UCL_{95} on the mean and the maximum detected concentration for zinc results in hazards $\geq$ 1.0 for a single location. As seen from **Table 6-8** zinc's UCL_{95} on the mean concentration is 704 mg/kg, while its maximum detected concentration (at station WBGss-146) is 24,900 mg/kg. **Figure J.23** indicates that a single location near Pad #45 produces a hazard between 1.0 and 3.0, due to the 24,900 mg/kg concentration of zinc from that location (WBGss-146). All other locations produce hazards < 1.0.

On-site resident farmer indirect exposure to surface soil hazards. As expected (based on the results of the aggregated risk evaluation, which produced ten noncarcinogenic COCs), some locations show a total hazard $\geq$

1.0 for the on-site resident farmer exposed indirectly to the surface soil. As seen from **Figure J.23**, the following locations produced hazards $\geq$ 1.0, with most of these locations (marked with an asterisk) producing risks $\geq 10^{-4}$:

- WBGss-003 (near Pad #3) *
- WBGss-004 (near Pad #4) *
- WBGss-005 (near Pad #5) *
- WBGss-006 (near Pad #6) *
- WBGss-008 (near Pad #8) *
- WBGss-022 (near Pad #29)
- WBGss-023 (near Pad #30) *
- WBGss-024 (between Pad #30 and Pad #32) *
- WBGss-025 (near Pad #32) *
- WBGss-026 (near Pad #33) *
- WBGss-027 (near Pad #34)
- WBGss-030 (near Pad #37) *
- WBGss-032 (near Pad #37) *
- WBGss-033 (near Pad #37) *
- WBGss-034 (near Pad #38) *
- WBGss-035 (near Pad #38) *
- WBGss-037 (near Pad #40) *
- WBGss-038 (near Pad #41) *
- WBGss-042 (near Pad #46) *
- WBGss-043 (near Pad #47)
- WBGss-045 (near Pad #49) *
- WBGss-046 (near Pad #50) *
- WBGss-047 (near Pad #51) *
- WBGss-049 (near Pad #53) *
- WBGss-054 (near Pad #58) *
- WBGss-055 (near Pad #59) *
- WBGss-057 (near Pad #60) *
- WBGss-058 (near Pad #60) *
- WBGss-059 (near Pad #61) *
- WBGss-061 (near Pad #62)
- WBGss-062 (near Pad #62) *
- WBGss-063 (near Pad #63)
- WBGss-064 (near Pad #63)
- WBGss-067 (near Pad #65) *
- WBGss-069 (near Pad #66) *
- WBGss-070 (near Pad #67) *
- WBGss-071 (near Pad #67) *
- WBGss-072 (near Pad #68) *
- WBGss-073 (near Pad #68) *
- WBGss-106 (near Pad #37)
- WBGss-107 (near Pad #37) *
- WBGss-108 (near Pad #38) *
- WBGss-109 (near Pad #38)
- WBGss-110 (near Pad #38) *

- WBGss-111 (near Pad #40) *
- WBGss-112 (near Pad #40) *
- WBGss-114 (near Pad #58) *
- WBGss-115 (near Pad #58)
- WBGss-116 (near Pad #58) *
- WBGss-118 (near Pad #59) *
- WBGss-120 (near Pad #60) *
- WBGss-121 (near Pad #60) *
- WBGss-122 (near Pad #60) *
- WBGss-126 (near Pad #61) *
- WBGss-128 (near Pad #62) *
- WBGss-129 (near Pad #62)
- WBGss-131 (near Pad #66)
- WBGss-132 (near Pad #66) *
- WBGss-133 (near Pad #66) *
- WBGss-134 (near Pad #66) *
- WBGss-135 (near Pad #66) *
- WBGss-136 (near Pad #67)
- WBGss-137 (near Pad #67)
- WBGss-139 (near Pad #67) *
- WBGss-140 (near Pad #67) *
- WBGss-141 (near Pad #68) *
- WBGss-142 (near Pad #68) *
- WBGss-143 (near Pad #68) *
- WBGss-144 (between Pad #45 and Pad #60) *
- WBGss-145 (between Pad #45 and Pad #60) *
- WBGss-146 (near Pad #45) *
- WBGss-147 (near Pad #45) *
- WBGss-148 (near Pad #45) *
- WBGss-149 (near Pad #45) *
- WBGss-168 (near Pad #66) *
- WBGss-169 (near Pad #59)
- WBGss-170 (near Pad #58) *
- WBGss-171 (near Pad #58)
- WBGss-172 (near Pad #59) *
- WBGss-173 (near Pad #60) *
- WBGss-174 (near Pad #60) *
- WBGss-175 (near Pad #37) *
- WBGss-176 (near Pad #68) *
- WBGss-177 (near Pad #68) *
- WBGss-178 (near Pad #67) *
- WBGss-179 (near Pad #67) *
- WBGss-187 (near Pad #37) *
- WBGss-188 (near Pad #70)
- WBGss-189 (near Pad #70)
- WBGss-193 (near Pad #62)
- WBGss-194 (near Pad #62).

6.5.3 Remedial Goal Options

To support the remedial alternative selection process, RGOs are developed for each chemical identified as a COC in the direct exposure pathways for the RVAAP/WBG BHHRA. RGOs are calculated using the methodology found in RAGS Part B (EPA 1991c), while incorporating site-specific parameter values for the WBG. These RGOs are risk-based concentrations that will be used in the FS to define the extent of contamination that must be remediated and will help cost various alternatives. RGOs are media- and chemical-specific concentrations and are calculated for COCs (as determined from the aggregated risk assessment, not the location-by-location risk assessment) within each land use/receptor scenario for a given medium.

The process for calculating RGOs for this BHHRA is a rearrangement of the risk (or hazard) equation, with the goal of obtaining the concentration that will produce a specific risk (or hazard). For example, the RGO for RDX at the cancer risk level of 10^{-4} for the National Guard receptor is the concentration of RDX that produces a risk of 10^{-4} when using the exposure parameters specific to the National Guard receptor.

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

$$\text{Risk} = (\text{Intake}) \times (\text{CSF}) \text{ and}$$

$$\text{Hazard} = (\text{Intake}) / (\text{RfD}), \text{ where}$$

The pathway-specific (e.g., drinking water ingestion) equations for the intake are provided in Section 6.3.3. Note that all of the intake equations shown in Section 6.3.3 include a concentration term multiplied by several other exposure parameters.

To obtain the RGO for a specific risk level (e.g., 10^{-4}), 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 drinking water ingestion pathway, note that by using the drinking water ingestion intake equation from Section 6.3.3 (equation 4) and the general risk equation from Section 6.5.1, the risk from ingestion of drinking water is calculated as

$$\text{Risk}_{\text{ing(water)}} = (\text{C x IR}_w \times \text{EF} \times \text{ED} \times \text{CSF}) / (\text{BW} \times \text{AT}).$$

To obtain the RGO at the 10^{-4} risk level for the ingestion of drinking water, a value of 10^{-4} is substituted in the equation above for $\text{Risk}_{\text{ing(water)}}$, and the equation is rearranged to solve for C. Thus, the general RGO equation at the 10^{-4} risk level for the ingestion of drinking water is calculated as

$$\text{RGO}_{\text{ing(water)}} \text{ at } 10^{-4} = (10^{-4} \times \text{BW} \times \text{AT}) / (\text{IR}_w \times \text{EF} \times \text{ED} \times \text{CSF}).$$

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

$$\text{RGO}_{\text{ing(water)}} \text{ at } 1.0 = (1.0 \times \text{BW} \times \text{AT} \times \text{RfD}) / (\text{IR}_w \times \text{EF} \times \text{ED}).$$

Thus, to obtain the ingestion of soil RGO at the 10^{-4} risk level for the National Guard receptor exposed to RDX, the parameter values for the National Guard receptor (from **Table 6-2**) and the chemical-specific parameter (oral CSF, from **Table J.4.2**) for RDX are used:

$RGO_{ing(water)}$ at 10^{-4} for RDX = $[(10^{-4})(70)(25550)] / (1)(180)(25)(0.11)]$

= 0.361 mg/L.

In this example, the RGO calculated is 0.361 mg/L, which will produce a drinking water ingestion risk of 10^{-4} for the National Guard receptor.

Note that if calculated RGOs are not physically possible, then the calculated RGO is adjusted accordingly. For example, if the calculated soil RGO is 5.5E+06 mg/kg, then the RGO is adjusted downward to 1.0E+06 mg/kg, because concentrations in mg/kg cannot be > 1.0E+06 mg/kg.

For this BHHRA, RGOs are calculated for each exposure route (e.g., ingestion), as well as the total chemical risk or hazard across all appropriate exposure routes. Carcinogenic RGOs are calculated and presented in this BHHRA for risk levels of 10^{-4} and 10^{-6}. To obtain the carcinogenic RGO at another risk level, one should adjust the RGO at 10^{-4} or 10^{-6} 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^{-5} risk level, one should multiply the RGO at the 10^{-6} risk level by 10 (and then check the result to ensure that the concentration is physically possible). Noncarcinogenic RGOs are calculated and presented in this BHHRA for hazard levels of 0.1 and 1.0. To find the noncarcinogenic RGO at another hazard level, one should adjust the RGO at the 0.1 or 1.0 hazard levels 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).

As seen in **Table 6-10**, COCs are identified for groundwater, sediment, subsurface soil, and surface soil. The unique list of COCs for each medium is obtained from the on-site resident farmer (since its parameters are the most conservative). For example, all COCs for groundwater are COCs for the on-site resident farmer. Therefore, the list of on-site resident farmer COCs (i.e., all chemicals with total risk > 10^{-6} or total HI > 1.0) is used to determine which RGOs are calculated, on a medium-by-medium basis. For completeness, RGOs are calculated for all receptor/medium combinations that have been evaluated in this BHHRA. For example, even though manganese is not a groundwater COC for the National Guard receptor, groundwater RGOs for manganese are calculated for both the on-site resident farmer and for the National Guard receptor (because manganese is a groundwater COC for the on-site resident farmer).

RGOs for the three groundwater COCs (manganese, chloroform, and RDX) have been calculated for the National Guard and on-site resident farmer receptors. These groundwater RGOs are presented in **Table 6-14**.

RGOs for the three sediment COCs [benzo(*a*)anthracene, benzo(*a*)pyrene, and benzo(*b*)fluoranthene] have been calculated for the seven land use/receptor combinations evaluated in this BHHRA. These sediment RGOs are presented in **Table 6-15**.

Because of the large uncertainty associated with the ingestion of foodstuffs (i.e., venison, beef, milk, and vegetables), the surface soil COC list for RGOs is based solely on the direct exposure pathways. Thus, RGOs are developed for the direct exposure pathways for the six COCs [arsenic, cadmium, TNT, benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX] previously developed from these pathways (see **Table 6-7**). These surface soil RGOs are calculated for all nine land use/receptor scenarios evaluated in this BHHRA and can be found in **Table 6-16**.

RGOs for the five subsurface soil COCs [cadmium, TNT, benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX] have been calculated for the National Guard, industrial worker, and on-site resident farmer receptors. These subsurface soil RGOs are presented in **Table 6-17**.

Table 6-14. Groundwater RGOs for Open Residential COCs

COC	DERMAL				INGESTION				INHALATION				TOTAL ACROSS ALL PATHWAYS			
	HQ= 0.1	HQ= 1.0	Risk= 10-6	Risk= 10-4	HQ= 0.1	HQ= 1.0	Risk= 10-6	Risk= 10-4	HQ= 0.1	HQ= 1.0	Risk= 10-6	Risk= 10-4	HI= 0.1	HI= 1.0	Risk= 10-6	Risk= 10-4
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																
Inorganics (mg/L)																
Manganese	5.39E+00	5.39E+01			6.53E-01	6.53E+00							5.82E-01	5.82E+00		
Organics (mg/L)																
Chloroform	6.58E-01	6.58E+00	3.02E-01	3.02E+01	1.42E-01	1.42E+00	6.52E-02	6.52E+00			4.91E-04	4.91E-02	1.17E-01	1.17E+00	4.86E-04	4.86E-02
RDX	4.62E-01	4.62E+00	3.92E-02	3.92E+00	4.26E-02	4.26E-01	3.61E-03	3.61E-01					3.90E-02	3.90E-01	3.31E-03	3.31E-01
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																
Inorganics (mg/L)																
Manganese	2.77E+00	2.77E+01			1.68E-01	1.68E+00							1.58E-01	1.58E+00		
Organics (mg/L)																
Chloroform	3.38E-01	3.38E+00	1.29E-01	1.29E+01	3.65E-02	3.65E-01	1.40E-02	1.40E+00			2.10E-04	2.10E-02	3.29E-02	3.29E-01	2.07E-04	2.07E-02
RDX	2.38E-01	2.38E+00	1.68E-02	1.68E+00	1.10E-02	1.10E-01	7.74E-04	7.74E-02					1.05E-02	1.05E-01	7.40E-04	7.40E-02

RGO = Remedial Goal Option; COC = Chemical of Concern; HQ = Hazard Quotient; HI = Hazard Index

Table 6-15. Sediment RGOs for Open Residential COCs

COC	DERMAL				INGESTION						INHALATION				TOTAL ACROSS ALL PATHWAYS			
	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Child HQ= 0.1	Child HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HI= 0.1	HI= 1.0	Risk= 10^{-6}	Risk= 10^{-4}
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Child Trespasser																		
Organics (mg/kg)																		
Benzo(a)anthracene			1.39E+01	1.39E+03					4.37E+02	4.37E+04			1.00E+06	1.00E+06			1.34E+01	1.34E+03
Benzo(a)pyrene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
Benzo(b)fluoranthene			1.39E+01	1.39E+03					4.37E+02	4.37E+04			1.00E+06	1.00E+06			1.34E+01	1.34E+03
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter - Trapper																		
Organics (mg/kg)																		
Benzo(a)anthracene			5.31E+00	5.31E+02					1.09E+02	1.09E+04			1.00E+06	1.00E+06			5.06E+00	5.06E+02
Benzo(a)pyrene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
Benzo(b)fluoranthene			5.31E+00	5.31E+02					1.09E+02	1.09E+04			1.00E+06	1.00E+06			5.06E+00	5.06E+02
LAND USE/RECEPTOR: National Guard - Managed Recreational/Child Trespasser																		
Organics (mg/kg)																		
Benzo(a)anthracene			1.39E+01	1.39E+03					4.37E+02	4.37E+04			1.00E+06	1.00E+06			1.34E+01	1.34E+03
Benzo(a)pyrene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
Benzo(b)fluoranthene			1.39E+01	1.39E+03					4.37E+02	4.37E+04			1.00E+06	1.00E+06			1.34E+01	1.34E+03
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter - Trapper																		
Organics (mg/kg)																		
Benzo(a)anthracene			5.31E+00	5.31E+02					1.09E+02	1.09E+04			1.00E+06	1.00E+06			5.06E+00	5.06E+02
Benzo(a)pyrene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
Benzo(b)fluoranthene			5.31E+00	5.31E+02					1.09E+02	1.09E+04			1.00E+06	1.00E+06			5.06E+00	5.06E+02
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																		
Organics (mg/kg)																		
Benzo(a)anthracene			3.43E+01	3.43E+03					1.05E+02	1.05E+04			1.00E+06	1.00E+06			2.59E+01	2.59E+03
Benzo(a)pyrene			3.43E+00	3.43E+02					1.05E+01	1.05E+03			1.14E+05	1.00E+06			2.59E+00	2.59E+02
Benzo(b)fluoranthene			3.43E+01	3.43E+03					1.05E+02	1.05E+04			1.00E+06	1.00E+06			2.59E+01	2.59E+03
LAND USE/RECEPTOR: Open Recreational/Recreator																		
Organics (mg/kg)																		
Benzo(a)anthracene			6.37E+00	6.37E+02					2.61E+02	2.61E+04			1.00E+06	1.00E+06			6.22E+00	6.22E+02
Benzo(a)pyrene			6.37E-01	6.37E+01					2.61E+01	2.61E+03			2.84E+05	1.00E+06			6.22E-01	6.22E+01
Benzo(b)fluoranthene			6.37E+00	6.37E+02					2.61E+02	2.61E+04			1.00E+06	1.00E+06			6.22E+00	6.22E+02
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																		
Organics (mg/kg)																		
Benzo(a)anthracene			1.36E+00	1.36E+02					8.75E-01	8.75E+01			2.54E+04	1.00E+06			5.33E-01	5.33E+01
Benzo(a)pyrene			1.36E-01	1.36E+01					8.75E-02	8.75E+00			2.54E+03	2.54E+05			5.33E-02	5.33E+00
Benzo(b)fluoranthene			1.36E+00	1.36E+02					8.75E-01	8.75E+01			2.54E+04	1.00E+06			5.33E-01	5.33E+01

RGO = Remedial Goal Option; COC = Chemical of Concern; HQ = Hazard Quotient; HI = Hazard Index

Table 6-16. Surface Soil RGOs for Open Residential COCs

COC	DERMAL				INGESTION						INHALATION				TOTAL ACROSS ALL PATHWAYS			
	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Child HQ= 0.1	Child HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HI= 0.1	HI= 1.0	Risk= 10^{-6}	Risk= 10^{-4}
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Child Trespasser																		
Inorganics (mg/kg)																		
Arsenic	3.44E+02	3.44E+03	8.93E+01	8.93E+03	8.21E+02	8.21E+03			2.13E+02	2.13E+04			5.90E+04	1.00E+06	2.43E+02	2.43E+03	6.28E+01	6.28E+03
Cadmium	2.80E+00	2.80E+01			2.74E+03	2.74E+04							4.84E+05	1.00E+06	2.80E+00	2.80E+01	4.84E+05	1.00E+06
Chromium	1.68E+02	1.68E+03			8.21E+03	8.21E+04					7.22E+05	1.00E+06	7.19E+04	1.00E+06	1.65E+02	1.65E+03	7.19E+04	1.00E+06
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	8.40E+01	8.40E+02	6.53E+02	6.53E+04	1.37E+03	1.37E+04			1.06E+04	1.00E+06					7.91E+01	7.91E+02	6.15E+02	6.15E+04
Benzo(a)pyrene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
Dibenzo(a,h)anthracene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
RDX	8.40E+02	8.40E+03	2.97E+02	2.97E+04	8.21E+03	8.21E+04			2.90E+03	2.90E+05					7.62E+02	7.62E+03	2.69E+02	2.69E+04
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Hunter - Trapper																		
Inorganics (mg/kg)																		
Arsenic	6.59E+02	6.59E+03	3.42E+01	3.42E+03	1.02E+03	1.02E+04			5.30E+01	5.30E+03			7.34E+03	7.34E+05	4.01E+02	4.01E+03	2.07E+01	2.07E+03
Cadmium	5.36E+00	5.36E+01			3.41E+03	3.41E+04							6.02E+04	1.00E+06	5.35E+00	5.35E+01	6.02E+04	1.00E+06
Chromium	3.21E+02	3.21E+03			1.02E+04	1.02E+05					4.49E+05	1.00E+06	8.95E+03	8.95E+05	3.11E+02	3.11E+03	8.95E+03	8.95E+05
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	1.61E+02	1.61E+03	2.50E+02	2.50E+04	1.70E+03	1.70E+04			2.65E+03	2.65E+05					1.47E+02	1.47E+03	2.28E+02	2.28E+04
Benzo(a)pyrene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
Dibenzo(a,h)anthracene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
RDX	1.61E+03	1.61E+04	1.14E+02	1.14E+04	1.02E+04	1.02E+05			7.23E+02	7.23E+04					1.39E+03	1.39E+04	9.82E+01	9.82E+03
LAND USE/RECEPTOR: Modified Caretaker - Managed Recreational/Security Guard - Maintenance Worker																		
Inorganics (mg/kg)																		
Arsenic	3.98E+02	3.98E+03	2.48E+01	2.48E+03	7.36E+02	7.36E+03			4.58E+01	4.58E+03			6.34E+03	6.34E+05	2.58E+02	2.58E+03	1.60E+01	1.60E+03
Cadmium	3.23E+00	3.23E+01			2.45E+03	2.45E+04							5.20E+04	1.00E+06	3.23E+00	3.23E+01	5.20E+04	1.00E+06
Chromium	1.94E+02	1.94E+03			7.36E+03	7.36E+04					3.24E+05	1.00E+06	7.74E+03	7.74E+05	1.89E+02	1.89E+03	7.74E+03	7.74E+05
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	9.70E+01	9.70E+02	1.81E+02	1.81E+04	1.23E+03	1.23E+04			2.29E+03	2.29E+05					8.99E+01	8.99E+02	1.68E+02	1.68E+04
Benzo(a)pyrene			3.85E-01	3.85E+01					9.41E+00	9.41E+02			1.02E+05	1.00E+06			3.69E-01	3.69E+01
Dibenzo(a,h)anthracene			3.85E-01	3.85E+01					9.41E+00	9.41E+02			1.02E+05	1.00E+06			3.69E-01	3.69E+01
RDX	9.70E+02	9.70E+03	8.23E+01	8.23E+03	7.36E+03	7.36E+04			6.24E+02	6.24E+04					8.57E+02	8.57E+03	7.27E+01	7.27E+03
LAND USE/RECEPTOR: National Guard - Managed Recreational/Child Trespasser																		
Inorganics (mg/kg)																		
Arsenic	3.44E+02	3.44E+03	8.93E+01	8.93E+03	8.21E+02	8.21E+03			2.13E+02	2.13E+04			5.90E+04	1.00E+06	2.43E+02	2.43E+03	6.28E+01	6.28E+03
Cadmium	2.80E+00	2.80E+01			2.74E+03	2.74E+04							4.84E+05	1.00E+06	2.80E+00	2.80E+01	4.84E+05	1.00E+06
Chromium	1.68E+02	1.68E+03			8.21E+03	8.21E+04					7.22E+05	1.00E+06	7.19E+04	1.00E+06	1.65E+02	1.65E+03	7.19E+04	1.00E+06
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	8.40E+01	8.40E+02	6.53E+02	6.53E+04	1.37E+03	1.37E+04			1.06E+04	1.00E+06					7.91E+01	7.91E+02	6.15E+02	6.15E+04
Benzo(a)pyrene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
Dibenzo(a,h)anthracene			1.39E+00	1.39E+02					4.37E+01	4.37E+03			9.51E+05	1.00E+06			1.34E+00	1.34E+02
RDX	8.40E+02	8.40E+03	2.97E+02	2.97E+04	8.21E+03	8.21E+04			2.90E+03	2.90E+05					7.62E+02	7.62E+03	2.69E+02	2.69E+04
LAND USE/RECEPTOR: National Guard - Managed Recreational/Hunter - Trapper																		
Inorganics (mg/kg)																		
Arsenic	6.59E+02	6.59E+03	3.42E+01	3.42E+03	1.02E+03	1.02E+04			5.30E+01	5.30E+03			7.34E+03	7.34E+05	4.01E+02	4.01E+03	2.07E+01	2.07E+03
Cadmium	5.36E+00	5.36E+01			3.41E+03	3.41E+04							6.02E+04	1.00E+06	5.35E+00	5.35E+01	6.02E+04	1.00E+06
Chromium	3.21E+02	3.21E+03			1.02E+04	1.02E+05					4.49E+05	1.00E+06	8.95E+03	8.95E+05	3.11E+02	3.11E+03	8.95E+03	8.95E+05
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	1.61E+02	1.61E+03	2.50E+02	2.50E+04	1.70E+03	1.70E+04			2.65E+03	2.65E+05					1.47E+02	1.47E+03	2.28E+02	2.28E+04

Table 6-16. Surface Soil RGOs for Open Residential COCs (continued)

COC	DERMAL				INGESTION						INHALATION				TOTAL ACROSS ALL PATHWAYS			
	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Child HQ= 0.1	Child HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HI= 0.1	HI= 1.0	Risk= 10^{-6}	Risk= 10^{-4}
Benzo(a)pyrene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
Dibenzo(a,h)anthracene			5.31E-01	5.31E+01					1.09E+01	1.09E+03			1.18E+05	1.00E+06			5.06E-01	5.06E+01
RDX	1.61E+03	1.61E+04	1.14E+02	1.14E+04	1.02E+04	1.02E+05			7.23E+02	7.23E+04					1.39E+03	1.39E+04	9.82E+01	9.82E+03
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																		
Inorganics (mg/kg)																		
Arsenic	5.53E+02	5.53E+03	3.44E+01	3.44E+03	1.28E+02	1.28E+03			7.95E+00	7.95E+02			1.99E+00	1.99E+02	1.04E+02	1.04E+03	1.52E+00	1.52E+02
Cadmium	4.49E+00	4.49E+01			4.26E+02	4.26E+03							1.63E+01	1.63E+03	4.45E+00	4.45E+01	1.63E+01	1.63E+03
Chromium	2.70E+02	2.70E+03			1.28E+03	1.28E+04					1.01E+02	1.01E+03	2.42E+00	2.42E+02	6.97E+01	6.97E+02	2.42E+00	2.42E+02
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	1.35E+02	1.35E+03	2.52E+02	2.52E+04	2.13E+02	2.13E+03			3.97E+02	3.97E+04					8.25E+01	8.25E+02	1.54E+02	1.54E+04
Benzo(a)pyrene			5.34E-01	5.34E+01					1.63E+00	1.63E+02			3.21E+01	3.21E+03			3.97E-01	3.97E+01
Dibenzo(a,h)anthracene			5.34E-01	5.34E+01					1.63E+00	1.63E+02			3.21E+01	3.21E+03			3.97E-01	3.97E+01
RDX	1.35E+03	1.35E+04	1.14E+02	1.14E+04	1.28E+03	1.28E+04			1.08E+02	1.08E+04					6.56E+02	6.56E+03	5.56E+01	5.56E+03
LAND USE/RECEPTOR: Open Industrial/Industrial Worker																		
Inorganics (mg/kg)																		
Arsenic	3.98E+02	3.98E+03	2.48E+01	2.48E+03	3.07E+01	3.07E+02			1.91E+00	1.91E+02			2.64E+02	2.64E+04	2.85E+01	2.85E+02	1.76E+00	1.76E+02
Cadmium	3.23E+00	3.23E+01			1.02E+02	1.02E+03							2.17E+03	2.17E+05	3.13E+00	3.13E+01	2.17E+03	2.17E+05
Chromium	1.94E+02	1.94E+03			3.07E+02	3.07E+03					1.35E+04	1.35E+05	3.22E+02	3.22E+04	1.18E+02	1.18E+03	3.22E+02	3.22E+04
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	9.70E+01	9.70E+02	1.81E+02	1.81E+04	5.11E+01	5.11E+02			9.54E+01	9.54E+03					3.35E+01	3.35E+02	6.25E+01	6.25E+03
Benzo(a)pyrene			3.85E-01	3.85E+01					3.92E-01	3.92E+01			4.26E+03	4.26E+05			1.94E-01	1.94E+01
Dibenzo(a,h)anthracene			3.85E-01	3.85E+01					3.92E-01	3.92E+01			4.26E+03	4.26E+05			1.94E-01	1.94E+01
RDX	9.70E+02	9.70E+03	8.23E+01	8.23E+03	3.07E+02	3.07E+03			2.60E+01	2.60E+03					2.33E+02	2.33E+03	1.98E+01	1.98E+03
LAND USE/RECEPTOR: Open Recreational/Recreator																		
Inorganics (mg/kg)																		
Arsenic	7.91E+02	7.91E+03	4.10E+01	4.10E+03	2.45E+03	2.45E+04			1.27E+02	1.27E+04			1.76E+04	1.00E+06	5.98E+02	5.98E+03	3.09E+01	3.09E+03
Cadmium	6.43E+00	6.43E+01			8.18E+03	8.18E+04							1.44E+05	1.00E+06	6.42E+00	6.42E+01	1.44E+05	1.00E+06
Chromium	3.86E+02	3.86E+03			2.45E+04	2.45E+05					1.00E+06	1.00E+06	2.15E+04	1.00E+06	3.80E+02	3.80E+03	2.15E+04	1.00E+06
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	1.93E+02	1.93E+03	3.00E+02	3.00E+04	4.09E+03	4.09E+04			6.36E+03	6.36E+05					1.84E+02	1.84E+03	2.86E+02	2.86E+04
Benzo(a)pyrene			6.37E-01	6.37E+01					2.61E+01	2.61E+03			2.84E+05	1.00E+06			6.22E-01	6.22E+01
Dibenzo(a,h)anthracene			6.37E-01	6.37E+01					2.61E+01	2.61E+03			2.84E+05	1.00E+06			6.22E-01	6.22E+01
RDX	1.93E+03	1.93E+04	1.36E+02	1.36E+04	2.45E+04	2.45E+05			1.73E+03	1.73E+05					1.79E+03	1.79E+04	1.26E+02	1.26E+04
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																		
Inorganics (mg/kg)																		
Arsenic	1.69E+02	1.69E+03	8.78E+00	8.78E+02	2.19E+01	2.19E+02	2.35E+00	2.35E+01	4.26E-01	4.26E+01			1.57E+02	1.57E+04	1.94E+01	1.94E+02	4.05E-01	4.05E+01
Cadmium	1.38E+00	1.38E+01			7.30E+01	7.30E+02	7.82E+00	7.82E+01					1.29E+03	1.29E+05	1.35E+00	1.35E+01	1.29E+03	1.29E+05
Chromium	8.26E+01	8.26E+02			2.19E+02	2.19E+03	2.35E+01	2.35E+02			9.63E+03	9.63E+04	1.92E+02	1.92E+04	5.96E+01	5.96E+02	1.92E+02	1.92E+04
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	4.13E+01	4.13E+02	6.43E+01	6.43E+03	3.65E+01	3.65E+02	3.91E+00	3.91E+01	2.13E+01	2.13E+03					1.94E+01	1.94E+02	1.60E+01	1.60E+03
Benzo(a)pyrene			1.36E-01	1.36E+01					8.75E-02	8.75E+00			2.54E+03	2.54E+05			5.33E-02	5.33E+00
Dibenzo(a,h)anthracene			1.36E-01	1.36E+01					8.75E-02	8.75E+00			2.54E+03	2.54E+05			5.33E-02	5.33E+00
RDX	4.13E+02	4.13E+03	2.92E+01	2.92E+03	2.19E+02	2.19E+03	2.35E+01	2.35E+02	5.81E+00	5.81E+02					1.43E+02	1.43E+03	4.84E+00	4.84E+02

RGO = Remedial Goal Option; COC = Chemical of Concern; HQ = Hazard Quotient; HI = Hazard Index

Table 6-17. Subsurface Soil RGOs for Open Residential COCs

COC	DERMAL				INGESTION						INHALATION				TOTAL ACROSS ALL PATHWAYS			
	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Child HQ= 0.1	Child HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HQ= 0.1	HQ= 1.0	Risk= 10^{-6}	Risk= 10^{-4}	HI= 0.1	HI= 1.0	Risk= 10^{-6}	Risk= 10^{-4}
LAND USE/RECEPTOR: National Guard - Managed Recreational/National Guard																		
Inorganics (mg/kg)																		
Cadmium	2.89E+01	2.89E+02			2.74E+03	2.74E+04							5.80E+04	1.00E+06	2.86E+01	2.86E+02	5.80E+04	1.00E+06
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	8.66E+02	8.66E+03	1.62E+03	1.62E+05	1.37E+03	1.37E+04			2.55E+03	2.55E+05					5.31E+02	5.31E+03	9.90E+02	9.90E+04
Benzo(a)pyrene			3.43E+00	3.43E+02					1.05E+01	1.05E+03			1.14E+05	1.00E+06			2.59E+00	2.59E+02
Dibenzo(a,h)anthracene			3.43E+00	3.43E+02					1.05E+01	1.05E+03			1.14E+05	1.00E+06			2.59E+00	2.59E+02
RDX	8.66E+03	8.66E+04	7.35E+02	7.35E+04	8.21E+03	8.21E+04			6.97E+02	6.97E+04					4.22E+03	4.22E+04	3.58E+02	3.58E+04
LAND USE/RECEPTOR: Open Industrial/Industrial Worker																		
Inorganics (mg/kg)																		
Cadmium	3.23E+00	3.23E+01			1.02E+02	1.02E+03							2.17E+03	2.17E+05	3.13E+00	3.13E+01	2.17E+03	2.17E+05
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	9.70E+01	9.70E+02	1.81E+02	1.81E+04	5.11E+01	5.11E+02			9.54E+01	9.54E+03					3.35E+01	3.35E+02	6.25E+01	6.25E+03
Benzo(a)pyrene			3.85E-01	3.85E+01					3.92E-01	3.92E+01			4.26E+03	4.26E+05			1.94E-01	1.94E+01
Dibenzo(a,h)anthracene			3.85E-01	3.85E+01					3.92E-01	3.92E+01			4.26E+03	4.26E+05			1.94E-01	1.94E+01
RDX	9.70E+02	9.70E+03	8.23E+01	8.23E+03	3.07E+02	3.07E+03			2.60E+01	2.60E+03					2.33E+02	2.33E+03	1.98E+01	1.98E+03
LAND USE/RECEPTOR: Open Residential/On-Site Resident Farmer																		
Inorganics (mg/kg)																		
Cadmium	1.38E+00	1.38E+01			7.30E+01	7.30E+02	7.82E+00	7.82E+01					1.29E+03	1.29E+05	1.35E+00	1.35E+01	1.29E+03	1.29E+05
Organics (mg/kg)																		
2,4,6-Trinitrotoluene	4.13E+01	4.13E+02	6.43E+01	6.43E+03	3.65E+01	3.65E+02	3.91E+00	3.91E+01	2.13E+01	2.13E+03					1.94E+01	1.94E+02	1.60E+01	1.60E+03
Benzo(a)pyrene			1.36E-01	1.36E+01					8.75E-02	8.75E+00			2.54E+03	2.54E+05			5.33E-02	5.33E+00
Dibenzo(a,h)anthracene			1.36E-01	1.36E+01					8.75E-02	8.75E+00			2.54E+03	2.54E+05			5.33E-02	5.33E+00
RDX	4.13E+02	4.13E+03	2.92E+01	2.92E+03	2.19E+02	2.19E+03	2.35E+01	2.35E+02	5.81E+00	5.81E+02					1.43E+02	1.43E+03	4.84E+00	4.84E+02

RGO = Remedial Goal Option; COC = Chemical of Concern; HQ = Hazard Quotient; HI = Hazard Index

6.6 UNCERTAINTY ANALYSIS

In estimating exposure and risks to receptors from contact with contaminated media, assumptions are made that incorporate the uncertainties inherent in the process. This section identifies the uncertainties associated with each step of the risk assessment process and, where possible, quantifies those uncertainties. Uncertainties are not cumulative and 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.

In addition, the determination of the chemical form of certain analytes is subject to various assumptions. For example, because of the limitations of the analytical technique used to determine the oxidation state of chromium in the field, all detected chromium is conservatively assumed during the COPC selection process to be in the oxidized form [chromium (VI)], by far the most toxic form of the element. Furthermore, in most media, the reduced form of chromium [chromium (III)] would be expected to be much more common; therefore, the evaluation of all chromium data as chromium (VI) is a highly conservative (in terms of protecting human health) assumption. Similarly, assumptions concerning the chemical form of metallic thallium have been made in order to evaluate thallium in this human health risk assessment. The most toxic form of thallium (thallium carbonate) is assumed in evaluating thallium in this BHHRA.

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 (from scientific research) becomes available; these periodic changes in toxicity values may cause the PRG values to change as well.

Uncertainty can be introduced in the data aggregation process. Any changes to criteria governing how data are grouped in the aggregation process affect the summary statistics for the aggregates. For example, if data from a single sample are removed from an aggregate, then the maximum detected concentration could change for the aggregate. These changes could affect whether an analyte remains on or is removed from the COPC list for that aggregate (since the maximum detected concentration is used in the PRG screening process). Other summary statistics could be affected as well.

Representative concentrations and other statistics are calculated in this BHHRA based on the assumption that the samples collected are truly random samples. In some cases, the data may not have been taken randomly, but rather may have been biased to identify high contaminant concentration locations. Seasonal variations in the data may also exist (especially with the groundwater and surface water data), which may not have been captured in the calculation of the concentrations for the COPCs.

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 removal processes, such as volatilization, leaching, and/or biodegradation). Therefore, exposure concentrations are assumed to be 100 percent of the measured or estimated concentrations in the media.

Uncertainty exists in the use of data from both sampling phases, in the process of characterizing current conditions at the site. The use of data collected over long intervals of time leads to uncertainties. The use of multiple laboratories for the two phases of data also causes uncertainties.

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 specify 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 SRC list and have a mixture of detected and non-detected concentrations, risk calculations may be affected. Risks may be overestimated as a result of some analyte concentrations being reported as nondetected at the method detection limit, which may be greater than the PRG concentration (when the actual concentration is much smaller than the method detection limit). Risks may also be underestimated because some analytes that are not detected are removed from the SRC list. If the concentrations of these analytes are below the minimum detectable level but above the PRG, the risk from these analytes would not be included in the risk assessment finding.

Common laboratory contaminants [e.g., bis(2-ethylhexyl)phthalate] appear on both the SRC list and on the COPC list. In the data assessment process elevated levels of these common laboratory contaminants can be evaluated to see if the detected concentrations are "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. When the blank data are not available, then this check cannot be made and there is the possibility that false positive data may have been included in the determination of SRCs and COPCs.

The selection of COPCs in this BHHRA relied primarily on analyte concentrations obtained as the result of field sampling of primary and secondary media assessed for the RI. The sources of SRCs are addressed in the selection of contaminants in exposure media for current environmental conditions. However, under future land use conditions, other contaminants not currently accounted for, particularly those that are either currently contained or that have slow transport velocities, may appear in secondary media at concentrations that could contribute to the calculated risk.

6.6.2 Uncertainties Associated with the Exposure Assessment

Uncertainty is also introduced through the data aggregation process of estimating representative exposure concentrations in the analyzed media. First, the frequency of detection is determined for each analyte. Then, for analytes with at least one detected concentration, the results are used to calculate the mean analyte concentration and UCL_{95} on the mean concentration. The maximum detected concentration is then compared against the UCL_{95} on the mean concentration, and the smaller of these two concentrations is used as the exposure concentration for the analyte. This method may underestimate the exposure concentration in small datasets from areas with a high degree of variability.

Some 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 specify how samples are to be selected and handled and how strictly these procedures are followed. QA/QC procedures are used to minimize uncertainties; however, sampling errors, laboratory analysis errors, and data analysis errors can and do occur. Moreover, some current analytical methods are limited in their ability to achieve detection limits appropriate for use in risk assessment. Therefore, risks may be overestimated as a result of analyte concentrations being reported at the method detection limit, which may be greater than the concentration at which adverse health effects could occur. Additional uncertainties are introduced by detection limits that differ among the various datasets; these uncertainties are especially

noticeable in the historical (i.e., Phase I) datasets. In addition, risks may be underestimated if chemical concentrations are above risk criteria, but below detection limits and reported as nondetects.

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 concentrations, and sampling and analysis of the media. For each primary exposure pathway chosen for analysis in this BHHRA, assumptions are made concerning the parameters, the routes of exposure, the amount of contaminated media a receptor can be exposed to, and intake rates for different routes of exposure. In the absence of site-specific data, the assumptions used are consistent with EPA-approved parameters and default values which are assumed to be representative of the potentially exposed populations (EPA 1989c, 1989d, 1991b, 1991c, 1992a, 1996d). All contaminant exposures and intakes are assumed to be from the site-related exposure media (i.e., no other sources contribute to the receptor's health risk). Selected intake rates and population characteristics (i.e., weight, lifespan, activities) are assumed to be representative of the exposed population.

Moderate uncertainty can be introduced in the data aggregation process of estimating a representative exposure concentration in the analyzed media. First, the detection status is determined for each analyte for each sample result. All non-detected values are considered at one-half the reported nondetected value. For analytes with at least one detected concentration, a statistical test (the Shapiro-Wilk test) is performed to determine whether a normal or lognormal distribution best fits the concentration distribution. The analyte's mean concentration and UCL_{95} on the mean concentration are calculated using both the detected values (at face value) and the nondetected values (at one-half reported value). The maximum detected concentration is then compared against the UCL_{95} on the mean concentration; the smaller of these two measures is used as the analyte's representative exposure concentration. This method may moderately overestimate the exposure concentration. In addition, when the resulting individual contaminant risks are summed, the compounding conservatism will likely result in an overestimate of the UCL_{95} of the summed risk.

Note that for the dermal contact with soil pathway, no exposure time is included in the equation. This is related to the assumption that the receptor may not bathe (i.e., remove the soil on the skin surface) for 24 hours following the initial exposure; therefore, the receptor is actually exposed to the soil contaminants for a 24-hour period. This may overestimate the risk associated with dermal contact with soil. 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 upperbound values are combined in estimating exposure for any one pathway, the resulting risks can be in excess of the 99th percentile and therefore outside 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 risk.

Uncertainties associated with the ingestion of foods (e.g., venison, beef, milk, vegetables) include assumptions made regarding frequency of exposure and quantity consumed, as well as added uncertainties in the bio-uptake factors used in these risk models.

6.6.3 Uncertainties Related to Toxicity Information

The methodology used to develop a noncarcinogenic 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 health data are available) and the most sensitive endpoint measured. Uncertainties exist in the experimental dataset 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 [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 are 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 multiples 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 and RfC toxicity values, exact safe levels of exposure for humans are not known. For noncarcinogenic 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 carcinogenic potential of a chemical can be increased through a two-part evaluation, involving (1) a weight-of-evidence assessment to determine the likelihood that a chemical is a 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 weight-of-evidence studies of humans and laboratory animals (EPA 1989c, 1996c, 1997b, 1998a): (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 carcinogen; (4) Group D, not classified as to human carcinogenicity; and (5) Group E, evidence of no carcinogenic effects to humans.

The slope factor 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; the linear equation is valid only at risk levels below 1E-02. For sites with very high chemical concentrations (i.e., with risks above 1.0E-02), an alternate calculation is performed by using the "one-hit" equation (EPA 1989a):

$$[\text{risk} = 1 - \exp(-\text{CDI} \times \text{SF})] \; . \qquad \textbf{(15)}$$

The values used to represent the dose-response relationship have chemical-specific uncertainties, which are embedded in the toxicity values; these factors are incorporated to represent uncertainty associated with the source of the data, duration of the study, extrapolations from short-term to long-term exposures, intrahuman or interspecies variability, and other special considerations.

For several analytes, no toxicity information for either the noncarcinogenic or carcinogenic health effects to humans is available in EPA's IRIS (EPA 1998a) or HEAST (EPA 1997b). The carcinogenic potential has not been evaluated for some chemicals lacking EPA-approved toxicity values. In addition, some analytes have been assigned a weight-of-evidence classification for carcinogenicity (EPA 1989c) but have not been assigned a slope factor. Therefore, until and unless additional toxicity information allows the derivation of toxicity factors, potential risk from certain analytes cannot be quantified.

The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. The toxicological data (slope factors 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, which also cause 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 in 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 could vary significantly with the chemical form present in the medium or media of concern; for example, risks from metals may be overestimated because they are conservatively assumed to be in their most toxic forms.

Uncertainties are associated with the %GI values used to modify the oral toxicity values that are used to determine dermal risks and HQs (Section 6.4.3). Similar uncertainties are associated with the toxicity equivalency factors values used to estimate risks from exposure to PAHs (Section 6.4.4). Many potential uncertainties are associated with the toxicity data used in this BHHRA and can affect the risk, HQ, and COC determinations (Section 6.4.8).

Furthermore, in the absence of EPA-approved toxicity values for two specific chemicals [arsenic and benzo(*a*)pyrene], withdrawn and/or provisional values have been used in the quantification of risks and hazards for the RVAAP/WBG COPCs (**Table J.4.2**). For these two COPCs, the toxicity values have higher uncertainties associated with them (because they are withdrawn/provisional values). If these COPCs are identified as COCs in this BHHRA, caution should be used, and a closer look at the withdrawn/provisional value(s) is appropriate when determining cleanup levels for these COCs.

6.6.4 Uncertainties and Assumptions in the Risk Characterization

Risk assessment as a scientific activity is subject to uncertainty (**Table J.6.1**), although the methodology used in this BHHRA follows EPA guidelines. As noted earlier, the risk evaluation in this report is subject to uncertainty pertaining to sampling and analysis, selection of COPCs, exposure assessment estimations, and availability of toxicological data.

Uncertainties related to the summation of HQs and carcinogenic risk estimates across chemicals and pathways are a primary uncertainty in the risk characterization. In the absence of information on the toxicity of specific chemical mixtures, additive (i.e., cumulative) risks and HQs are assumed (EPA 1989c). Limitations of this approach for noncarcinogens are: (1) the effects of a mixture of chemicals are generally unknown; it is possible that the interactions could be synergistic or antagonistic; (2) the RfDs have different accuracy and precision and are not based on the same severity or effect; and (3) HQ or CDI summation is most properly applied to compounds that induce the same effects by the same mechanism. Therefore, the potential for occurrence of noncarcinogenic 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, adaptivity for risks and HQs is assumed for this BHHRA. However, because total risks and HIs are usually driven by a few specific 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 BHHRA, COCs are selected for a given medium/land use scenario, as chemicals with individual risks $\geq$ 1.0E-06 and/or individual HQs $\geq$ 0.1, for a given medium within a scenario with a total risk (across all chemicals) $\geq$ 1.0E-04 and/or a total HI (across all chemicals) $\geq$ 1.0, respectively.

Potential risks and hazards are not determined for the eight COPCs that could not be evaluated quantitatively due to the unavailability of toxicity information and/or values for those analytes. As seen from Table J.2.6, these eight qualitative COPCs are aluminum, copper, lead, 2-methylnaphthalene, benzo(*g,h,i*)perylene, nitrocelluloseas N, nitroglycerin, and phenanthrene. Therefore, uncertainties exist which could underestimate the risks/hazards to human health.

6.7 SUMMARY AND CONCLUSIONS

The BHHRA is conducted to evaluate risks and hazards at RVAAP/WBG for a number of potential future land use scenarios including National Guard, open industrial, open recreational, and open residential. Results have been presented for all scenarios and exposure pathways; however, the size of the AOC and the quantity of data available require several layers of screening in order to focus on the significant contaminants, effected areas, and exposure pathways. The following screenings of datasets and BHHRA results are used to generate conclusions regarding human health risks and hazards at RVAAP/WBG:

- background comparison (metals only),
- RBSC screening,
- identification of COPCs,
- identification of COCs, and
- determination of most likely receptors.

Table 6-18 presents a summary of all receptors evaluated in this BHHRA and identifies the contaminants that produce large risks ($>10^{-4}$) or hazards (>1.0).

Risks and hazards are evaluated for a number of exposure scenarios, for both current and future land uses/receptors. Although it is possible for any of these scenarios to reflect actual conditions in the future, some are more likely than others, based on the site setting and anticipated future use. This section focuses on summarizing risks and hazards for the exposure scenarios that are considered to be most likely for specific areas of RVAAP/WBG. As discussed in Section 6.3, the exposure aggregate for RVAAP/WBG is the entire site itself (i.e., all data for a given medium aggregated and evaluated as a whole). Conclusions are formulated from the results of the aggregated analyses.

The most likely receptors in the future are the National Guardsman, as well as the hunter/trapper, security guard/maintenance worker, and industrial worker; the child trespasser is also considered as a potential receptor. The open residential scenario is evaluated as an upper bound (i.e., worst-case) scenario for this BHHRA.

National Guard Receptor

The National Guard receptor in the National Guard/managed recreational land use scenario considers exposure to groundwater, sediment, surface water, surface soil, and subsurface soil. Although there are some COCs for the exposure to groundwater (chloroform and RDX) and surface soil (arsenic, cadmium, chromium, TNT, and RDX), the exposure aggregate shows no hazards > 1.0 or risks > 10^{-4} from any of these media.

Hunter/Trapper Receptor

The hunter/trapper is considered to be the same receptor for both the modified caretaker/managed recreational land use and for the National Guard/managed recreational land use. This receptor is evaluated for exposure to sediment, surface water, and surface soil (both direct and indirect exposures to surface soil). Although there is

Table 6-18. Summary of COCs with Risks > 10^{-4} or Hazards > 1.0 for All Receptors

Land Use	Receptor	Media	Significant COCs
Modified Caretaker–Managed Recreational	Security Guard/Maintenance Worker	Surface Soil (direct contact)	None
	Hunter/Trapper	Surface Soil (direct and indirect contact), Sediment, Surface Water	None
	Child Trespasser	Surface Soil (direct contact), Sediment, Surface Water	None
National Guard/Managed Recreational	National Guard	Surface Soil (direct contact), Sediment, Surface Water	None
	Hunter/Trapper	Surface Soil (direct and indirect contact), Sediment, Surface Water	None
	Child Trespasser	Surface Soil (direct contact), Sediment, Surface Water	None
Open Recreational	Recreator	Surface Soil (direct contact), Sediment, Surface Water	None
Open Industrial	Industrial Worker	Surface Soil (direct contact), Subsurface Soil	None
Open Residential	On-site Resident Farmer	Sediment, Surface Water	None
		Subsurface Soil	Cadmium; TNT
		Groundwater	Manganese
		Surface Soil (direct contact)	Cadmium; TNT; RDX
		Surface Soil (indirect contact)	Antimony; arsenic; barium; cadmium; chromium; zinc; TNB; TNT; benzo(*a*)pyrene; dibenzo(*a,h*)anthracene; indeno(1,2,3-*cd*)pyrene; HMX; and RDX

one COC for the direct exposure to surface soil (RDX), the exposure aggregate shows no hazards > 1.0 or risks > 10^{-4} from any of these media.

Security Guard/Maintenance Worker Receptor

The security guard/maintenance worker in the modified caretaker/managed recreational land use scenario considers exposure to surface soil. Although there is one COC for the exposure to surface soil (RDX), the exposure aggregate shows no hazards > 1.0 or risks > 10^{-4} from this medium.

Industrial Worker Receptor

The industrial worker in the open industrial land use scenario considers exposure to surface and subsurface soil. Although there are some COCs for the exposure to surface soil [arsenic, TNT, benzo(*a*)pyrene, and RDX] and subsurface soil [TNT, benzo(*a*)pyrene, and RDX], the exposure aggregate shows no hazards > 1.0 or risks > 10^{-4} to either medium.

Child Trespasser Receptor

The child trespasser is considered to be the same receptor for both the modified caretaker/managed recreational land use and for the National Guard/managed recreational land use. This receptor is evaluated for exposure to sediment, surface water, and surface soil. Under this scenario, there are no COCs for the child trespasser exposed to any of these media.

On-site Resident Farmer Receptor

The on-site resident farmer in the open residential land use scenario considers exposure to sediment, surface water, surface soil (direct and indirect), subsurface soil, and groundwater. Under this scenario, sediment exposure results in three COCs with risk between 10^{-6} and 10^{-4} [benzo(*a*)anthracene, benzo(*a*)pyrene, and benzo(*b*)fluoranthene]. There are no COCs for surface water exposure for the on-site resident farmer. In addition to two COCs with risk between 10^{-6} and 10^{-4} (chloroform and RDX), one COC with a hazard > 1.0 is found for exposure to groundwater. Manganese produces a hazard > 1.0 (from the dermal contact pathway) based on the lone groundwater concentration detected above its background level.

For direct contact with surface soil, there are some COCs with risk between 10^{-6} and 10^{-4} [arsenic, benzo(*a*)pyrene, and dibenzo(*a,h*)anthracene], as well as three COCs with risks > 10^{-4} or hazards > 1.0: cadmium (dermal contact); TNT (child ingestion); and RDX (child ingestion).

For indirect contact with surface soil (i.e., ingestion of venison, beef, milk, and vegetables), there are two COCs with risks between 10^{-6} and 10^{-4} [benzo(*a*)anthracene and benzo(*b*)fluoranthene]. Thirteen COCs had risks > 10^{-4} or hazards > 1.0 for this exposure, mostly from ingestion of home-grown vegetables, including: antimony; arsenic; barium; cadmium; chromium (evaluated with the toxicity of hexavalent chromium); zinc; TNB; TNT; benzo(*a*)pyrene; dibenzo(*a,h*)anthracene; indeno(1,2,3-*cd*)pyrene; HMX; and RDX.

For subsurface soil, there are three COCs with risks between 10^{-6} and 10^{-4} [benzo(*a*)pyrene, dibenzo(*a,h*)anthracene, and RDX], as well as two COCs with hazard > 1.0 (cadmium, from dermal contact): and risk > 10^{-4} (TNT, from child ingestion).

Conclusion

As seen from **Table 6-18**, the only COCs with risks > 10^{-4} or hazards > 1.0 are for the on-site resident farmer receptor. This future potential receptor is not considered to be the most likely receptor. Therefore, no human health COCs with risks > 10^{-4} or hazards > 1.0 exist for the most likely receptors.

6.8 TOXICITY PROFILES

6.8.1 Inorganics

Aluminum. Aluminum is a silvery, ductile metal with industrial hazards associated with its reactivity. Aluminum dust is moderately flammable/explosive by heat, flame, or chemical reaction with powerful oxidizers (Lewis 1991).

The following toxicity summary for aluminum is taken from Biomedical and Environmental Information Analysis System (BEIAS) 1995.

Aluminum is poorly absorbed and efficiently eliminated; however, when absorption does occur, aluminum is distributed mainly in bone, liver, testes, kidneys, and brain (ATSDR 1990a). Aluminum may be involved in Alzheimer's disease (dialysis dementia) and in Amyotrophic Lateral Sclerosis and Parkinsonism-Dementia Syndromes of Guam (Guam ALS-PD complex) (ATSDR 1990a; Goyer 1991). Aluminum content of brain, muscle, and bone increases in Alzheimer's patients. Neurofibrillary tangles are found in patients suffering from aluminum encephalopathy and Alzheimer's disease. Symptoms of "dialysisdementia" include speech disorders, dementia, convulsions, and myoclonus. People of Guam and Rota have an unusually high incidence of neurodegenerative diseases. The volcanic soil in the region of Guam where the high incidence of ALS-PD occurs contains high levels of aluminum and manganese. Neurological effects have also been observed in rats orally exposed to aluminum compounds.

The respiratory system appears to be the primary target following inhalation exposure to aluminum. Alveolar preteinosis has been observed in guinea pigs, rats, and hamsters exposed to aluminum powders (Gross, Harley, and de Treville 1973). Rats and guinea pigs exposed to aluminum chlorohydrate exhibited an increase in alveolar macrophages, increased relative lung weight, and multifocal granulomatous pneumonia (Cavender, Steinhagen, and Cockrell 1978).

No decrease in reproductive capacity, hormonal abnormalities, or testicular histopathology was observed in male rats exposed to aluminum in drinking water for 90 days (Dixon, Sherins, and Lee 1979). However, male rats exposed to aluminum (as aluminum chloride) via gavage for 6 months exhibited decreased spermatozoa counts and sperm motility, and testicular histological and histochemical changes (Krasovskii, Vasulovich, and Charie 1979).

Subchronic and chronic reference doses and reference concentrations have not been derived for aluminum.

Male rats exposed to drinking water containing aluminum (as aluminum potassium sulfate) for a lifetime exhibited increases in unspecified malignant and nonmalignant tumors (Schroeder and Mitchener 1975a), and similarly exposed female mice exhibited an increased incidence of leukemia (Schroeder and Mitchener 1975b). Rats and guinea pigs exposed via inhalation to aluminum chlorohydrate developed lung granulomas (Cavender, Steinhagen, and Cockrell 1978), while granulomatous foci developed in similarly exposed male hamsters (Drew et al. 1974).

The EPA is currently reviewing aluminum for potential human health hazards. There is no weight-of-evidence carcinogenic classification currently assigned.

Antimony. Antimony is a naturally occurring metalloid element that displays both metallic and nonmetallic properties and exists in valence states of (III) and (V). Metallic antimony and a few trivalent antimony compounds are the most significant forms in terms of exposure potential and toxicity. Antimony is used in metallurgical processes, paints and enamels, various textiles, rubber, and fire retardation (antimony trioxide). A common urban air pollutant, antimony can be inhaled, and it can also be ingested in contaminated food (BEIAS 1995).

The primary target organ for acute oral exposure to antimony appears to be the gastrointestinal tract (irritation, diarrhea, vomiting), and targets for long-term exposure are blood (hematological disorders) and the liver (mild hepatotoxicity). Inhalation exposure to antimony affects the respiratory tract (pneumoconiosis, restrictive airway disorders), with secondary targets being the cardiovascular system (altered blood pressure and electrocardiograms) and kidneys (histological changes). Only limited evidence exists for reproductive disorders resulting from antimony exposure (BEIAS 1995).

EPA has calculated subchronic and chronic oral RfDs of 4E-4 mg/kg-d on the basis of decreased longevity and alteration of blood chemistry in rats that have been chronically exposed to potassium antimony tartrate in drinking water. Although some data indicate that long-term exposure of rats to antimony trioxide and trisulfide increased the incidence of lung tumors, EPA has not evaluated antimony or antimonials for carcinogenicity, and no weight-of-evidence classification is available (BEIAS 1995).

Arsenic. Arsenic is a metallic, steel-gray, crystalline, brittle, trivalent and pentavalent, solid, poisonous element that is commonly used in pesticides (BEIAS 1995).

Water-soluble inorganic arsenic compounds are absorbed through the gastrointestinal tract and lungs. Symptoms of acute inorganic arsenic poisoning in humans are nausea, anorexia, vomiting, epigastric and abdominal pain, and diarrhea. In addition, dermatitis, muscle cramps, cardiac abnormalities, hepatoxicity, bone marrow suppression and hematologic abnormalities, vascular lesions, and peripheral neuropathy have also been reported. Severe exposures can result in acute encephalopathy, congestive heart failure, stupor, convulsions, paralysis, coma, and death. Possible reproductive effects include a high frequency of spontaneous abortions and reduced birth weights. Occupational exposure studies show a clear correlation between exposure to arsenic and lung cancer mortality (BEIAS 1995).

The RfD for chronic and subchronic oral exposures (0.0003 mg/kg-d) is based on an NOAEL of 0.0008 mg/kg-d and an LOAEL of 0.014 mg/kg-d for hyperpigmentation, keratosis, and possible vascular complications in a human population consuming arsenic-contaminated drinking water. No subchronic and chronic RfCs have been derived for arsenic.

Studies indicate an increased lung cancer mortality observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic (EPA 1998a). EPA has placed inorganic arsenic in weight-of-evidence classification Group A, human carcinogen (BEIAS 1995).

Barium. Barium is a divalent alkaline-earth metal found only in combination with other elements in nature; the most important of these combinations are with peroxide, chloride, sulfate, carbonate, nitrate, and chlorate. The most likely source of barium in the atmosphere is industrial emissions. Because of the tendency of barium to form salts with limited solubility in soil and water, it is expected to have a residence time of hundreds of years and is not expected to be very mobile. Acidic conditions, however, will increase the

solubility of some barium compounds, facilitating their movement from the soil to groundwater. Trace amounts of barium were found in >99 percent of the surface water and finished drinking water samples, with average values of 43 and 28.6 µg/L, respectively, across the United States (BEIAS 1995).

The soluble salts of barium are toxic to mammalian systems. They are absorbed rapidly from the gastrointestinal tract; deposited in the muscles, lungs, and bone; and excreted primarily in the feces. Low doses of barium act as a muscle stimulant while higher doses affect the nervous system, eventually leading to paralysis. Acute and subchronic oral doses of barium cause vomiting and diarrhea, followed by decreased heart rate and elevated blood pressure. Higher doses result in cardiac irregularities, weakness, tremors, anxiety, and depression. Acute doses of about 0.8 g can cause death in humans from cardiac and respiratory failure (BEIAS 1995).

EPA has calculated a chronic and subchronic oral RfD of 0.07 mg/kg-d based on an NOAEL of 0.21 mg/kg-d in humans. EPA calculated an inhalation RfC of 0.005 mg/m^3 for subchronic and 0.0005 mg/m^3 for chronic exposure on the basis of the NOAEL for developmental effects in humans. Barium has not been evaluated for evidence of human carcinogenic potential (BEIAS 1995).

Cadmium. Cadmium is a naturally occurring element found worldwide in soils and rocks. The primary sources of environmental cadmium contamination are smelters and the burning of fossil fuels in power plants.

Cadmium is absorbed more efficiently through the lungs than by the gastrointestinal tract. Acute oral exposures to cadmium can cause vomiting, diarrhea, and abdominal pain, while longer-term oral exposure to cadmium affects the kidneys and possibly the skeletal system (Young 1991). Inhalation exposure to cadmium may cause headache, chest pains, muscular weakness, pulmonary edema, and death (Young 1991), while longer-term inhalation exposure also results in kidney damage (ATSDR 1989a; EPA 1980, 1984a).

Limited evidence shows possible adverse spermatogenic effects of cadmium in occupationally exposed workers (Barlow and Sullivan 1982). The results of genotoxicity and mutagenicity tests with cadmium are inconclusive. Some assays show positive results (certain mammalian cell culture assay systems), while other assays report negative findings (mouse bone marrow and mouse micronucleus assays) (ATSDR 1989a).

The IARC has found limited evidence indicating that cadmium and cadmium-containing compounds are carcinogenic in humans (IARC 1982). This determination was based on occupational epidemiology studies that have shown an increased risk of lung cancer in workers exposed to cadmium via inhalation. EPA has placed cadmium in weight-of-evidence Class B1, probable human carcinogen.

Chromium. Chromium is a metal that occurs in nature primarily as the mineral chromite. Although chromium exists in several valence states, the trivalent (III) and hexavalent (VI) valence states are the only two of any biological significance (Amdur, Doull, and Klassan 1991). Trivalent chromium is considered an essential element in man and animals.

Acute animal studies indicate that chromium (III) compounds are consistently less toxic than chromium (VI) (Friberg, Nordberg, and Vouk 1986), but neither oxidation state is very toxic by the oral route (Daugherty 1992). No adverse effects were observed in long-term drinking water studies in rats.

Chromium compounds (and particularly hexavalent compounds) are very strong skin irritants and sensitizers in humans, producing dermatitis, dermatosis, eczema, erythema, and skin ulceration. Exposure to chromium has caused respiratory effects such as nasal irritation, nasal ulcers, nasal perforation, asthmatic attacks, pneumoconiosis, bronchitis, and chronic lung congestion in humans under various occupational conditions (Daugherty 1992). Both hexavalent and trivalent chromium compounds are known to be nephrotoxic, with some reports indicating that they may also be hepatotoxic and neurotoxic (EPA 1984b).

Chromium compounds, both trivalent and hexavalent, have induced developmental effects in hamsters and mice (but only at maternally toxic doses) and testicular effects in rabbits after intraperitoneal, intravenous, or subcutaneous injections (EPA 1984b). Bacterial test systems have consistently demonstrated that chromium (VI) compounds are directly mutagenic while chromium (III) compounds are not (EPA 1984b). An increased frequency of chromosome aberrations in lymphocytes from workers exposed to chromates during production of such compounds has been reported (EPA 1984b), and several occupational epidemiology studies have shown that occupational exposure to chromium is associated with an increase in lung cancer deaths for workers. Evidence also suggests increased risk of developing nasal, pharyngeal, and gastrointestinal cancers (IARC 1980; Daugherty 1992). EPA has not given chromium (III) a weight-of-evidence classification; however, chromium (VI) has been placed in weight-of-evidence Group A, known human carcinogen (BEIAS 1995).

Copper. Copper occurs naturally in elemental form and as a component of many minerals. Because of its high electrical and thermal conductivity, it is widely used in the manufacture of electrical equipment. Common copper salts, such as the sulfate, carbonate, cyanide, oxide, and sulfide are used as fungicides, as components of ceramics and pyrotechnics, for electroplating, and for numerous other industrial applications (ACGIH 1986). Copper can be absorbed by the oral, inhalation, and dermal routes of exposure. It is an essential nutrient that is normally present in a wide variety of tissues (ATSDR 1990b; EPA 1987).

In humans, ingestion of gram quantities of copper salts may cause gastrointestinal, hepatic, and renal effects with symptoms such as severe abdominal pain, vomiting, diarrhea, hemolysis, hepatic necrosis, hematuria, proteinuria, hypotension, tachycardia, convulsions, coma, and death (USAF 1990). Gastrointestinal disturbances and liver toxicity have also resulted from long-term exposure to drinking water containing 2.2-7.8 mg Cu/L (Mueller-Hoecker et al. 1988; Spitalny et al. 1984). The chronic toxicity of copper has been characterized in patients with Wilson's disease, a genetic disorder causing copper accumulation in tissues. The clinical manifestations of Wilson's disease include cirrhosis of the liver, hemolytic anemia, neurologic abnormalities, and corneal opacities (Goyer 1991; ATSDR 1990b; EPA 1987). In animal studies, oral exposure to copper caused hepatic and renal accumulation of copper, liver and kidney necrosis at doses of >100 mg/kg/day; and hematological effects at doses of 40 mg/kg/day (EPA 1986a; Haywood 1985; 1980; Rana and Kumar 1978; Gopinath, Hall, and McHowell 1974; Kline, Hays, and Cromwell 1971).

Acute inhalation exposure to copper dust or fumes at concentrations of 0.075-0.12 mg Cu/m^3 may cause metal fume fever with symptoms such as cough, chills, and muscle ache (USAF 1990). Among the reported effects in workers exposed to copper dust are gastrointestinal disturbances, headache, vertigo, drowsiness, and hepatomegaly (Suciu et al. 1981). Vineyard workers chronically exposed to Bordeaux mixture (copper sulfate and lime) exhibit degenerative changes of the lungs and liver. Dermal exposure to copper may cause contact dermatitis in some individuals (ATSDR 1990b).

Oral or intravenous administration of copper sulfate increased fetal mortality and developmental abnormalities in experimental animals (Lecyk 1980; Ferm and Hanlon 1974). Evidence also indicates that copper compounds are spermicidal (ATSDR 1990b; Battersby, Chandler, and Morton 1982).

An RfD for elemental copper is not available. However, EPA established an action level of 1300 µg/L for drinking water (EPA 1991e). Data were insufficient to derive an RfC for copper.

No suitable bioassays or epidemiological studies are available to assess the carcinogenicity of copper. Therefore, EPA (1991d) has placed copper in weight-of-evidence Group D, not classifiable as to human carcinogenicity.

Lead. Lead has been used by humans for thousands of years because of its malleability, resistance to corrosion, and abundance. This metal can be a component of solder, paint, and gasoline, but these uses have declined dramatically in recent years as awareness of the toxicity associated with lead exposure has increased. Currently in the United States, the predominant use of lead is in batteries. Lead occurs at an average concentration of 10 mg/kg in soil, but soil levels are substantially elevated in many areas exposed to emissions from smelters and automobiles or in areas where lead-containing paint chips have fallen onto soils (BEIAS 1995).

Inhalation and oral RfD values for lead have not been derived by the EPA because it has not been possible to establish the NOAEL or LOAEL for this metal. Health effects have tentatively been associated with blood levels as low as 10 µg/dL (BEIAS 1995).

In the absence of an oral or inhalation RfD for lead, the EPA has developed an uptake/biokinetic model to estimate blood lead levels on the basis of total lead uptake from exposures via diet, drinking water, air, soil, and paint. Application of this model to potential exposures is not discussed in this report; however, further information can be obtained from EPA (BEIAS 1995).

At blood levels greater than 40 µg/dL, lead can cause miscarriage, sterility in males, anemia, and damage to the central nervous system and kidneys. Lead exposure resulting in these high blood levels is rare today. Blood levels of 30 µg/dL and higher have been associated with defects in vitamin D metabolism and with lowered intelligent quotient scores in children. At blood levels of 20 µg/dL and lower, the effects become more difficult to define. Some studies report a dose-related increase in blood pressure in adult males starting at blood levels of about 10 µg/dL. Additionally, the fetus and young children are particularly sensitive to lead toxicity; even low-level lead exposure during pregnancy and early childhood can cause reduced birth weight, premature birth, and delayed development (BEIAS 1995).

Lead can cause varied toxicological effects, depending on the level of exposure. From studies on rats and mice, the EPA has previously classified lead as a Group B2, probable human carcinogen. However, the doses that induce cancer are higher than those associated with other health effects of lead, such as reproductive toxicity, developmental toxicity, and increased blood pressure (BEIAS 1995).

Manganese. Manganese is an essential trace element in humans; however, prolonged exposure to elevated concentrations, either orally or by inhalation, can elicit serious toxic responses. The central nervous system is the primary target. Initial symptoms are headache, insomnia, disorientation, anxiety, lethargy, and memory loss; with continued exposure, these symptoms progress to motor disturbances, tremors, and difficulty in walking. Symptoms are similar to those seen with Parkinsonism that are often irreversible. Data from human epidemiological studies have been used to estimate LOAELs for central nervous system effects of 0.8 mg/kg-d for drinking water exposure and 0.34 mg/m^3 in air for inhalation exposure (BEIAS 1995).

Effects on reproduction (decreased fertility, impotence) have been observed in humans with inhalation exposure and in animals with oral exposure at the same or similar doses that produce the central nervous system effects. An increased incidence of coughs, colds, dyspnea during exercise, bronchitis, and altered lung ventilatory parameters have also been observed in humans and animals after inhalation exposure. A possible effect on the immune system may account for some of these respiratory symptoms (BEIAS 1995).

Because of the greater bioavailability of manganese from water, separate RfDs for water and diet were calculated. EPA calculated a chronic and subchronic RfD for drinking water of 0.005 mg/kg-d from a human NOAEL of 0.005 mg/kg-d, which was determined from an epidemiological study of human populations exposed for a lifetime to manganese concentrations in drinking water ranging from 3.6 to 2300 µg/L. EPA also calculated a chronic and subchronic RfD of 0.14 mg/kg-d for dietary exposure from a human NOAEL of

0.14 mg/kg-d, which was determined from a series of epidemiological studies. Although large populations with different concentrations of manganese in their diets were examined, no adverse effects attributable to manganese were seen in any of these groups. Both the drinking water and dietary RfDs were derived without uncertainty factors because manganese is essential in human nutrition and because exposure of the most sensitive groups was included in the populations examined. EPA indicates that the chronic RfD values are pending change (BEIAS 1995).

Although available data about possible carcinogenesis after injections of manganese chloride and manganese sulfate in mice are conflicting, the EPA weight-of-evidence classification is D, not classifiable as to human carcinogenicity (BEIAS 1995).

Thallium. Thallium, a naturally occurring elemental metal, is commonly found in minerals and as thallium salts. It can also be released into the environment from industrial sources such as coal-fired power plants, smelting operations, and cement factories. Atmospheric thallium contaminates surface soils by deposition allowing for the exposure of humans by oral, dermal, or inhalation routes. The most common nonoccupational sources of thallium exposure are contaminated food crops and tobacco. Although normally present in the urine of humans, elevated urine thallium concentrations have been associated with adverse health effects.

The primary targets of thallium toxicity are the nervous, integumentary, and reproductive systems. In humans, acute exposures produce paresthesia, retrobulbar neuritis, ataxia, delirium, tremors, and hallucinations. This implies central, peripheral, and autonomic nervous system involvement (Stokinger 1981; de Groot and Van Heijst 1988; Kazantzis 1986). Human and animal chronic exposures result in alterations of the brain, spinal cord, and peripheral nerves (Stokinger 1981; Manzo et al. 1983). In both humans and animals, alopecia is the most common indicator of long-term thallium poisoning (Stokinger 1981; Manzo et al. 1983).

An increased incidence of congenital malformations was found in children of parents exposed to thallium through the consumption of home-grown fruits and vegetables. However, a causal relationship between these effects and thallium exposure could not be confirmed (Dolgner et al. 1983). In animal studies, thallium compounds produced testicular effects in male rats and slight fetotoxicity and significant impairment of learning ability in the offspring of treated female rats (Formigli et al. 1986; Roll and Matthiaschk 1981; Bornhausen and Hagen 1984).

RfDs have been calculated for subchronic and chronic oral exposure to several thallium compounds. The values, derived from a single study where thallium treatment increased AST and LDH activities in rats, are based on NOAELs ranging from 0.23 to 0.28 mg/kg/day (EPA 1986b). The subchronic RfDs are 8.00E-04 (thallium sulfate, chloride, and carbonate) or 9.00E-04 mg/kg/day (thallium nitrate and acetate) (EPA 1994b), and the chronic RfDs are 8.00E-05 (thallium sulfate, chloride, and carbonate) or 9.00E-05 mg/kg/day (thallium nitrate and acetate) (EPA 1994d-g).

Data suitable for evaluating the carcinogenicity of thallium to humans or animals by ingestion, inhalation, or other routes of exposure were not found. Thallium sulfate, selenite, nitrate, chloride, carbonate, and acetate have been placed in EPA's weight-of evidence Group D, not classifiable as to human carcinogenicity based on inadequate human and animal data (EPA 1994d-i).

Zinc. Zinc, a naturally occurring metal commonly found in air, soil, water, and various foodstuffs, is an essential element in the human diet. Zinc, in a variety of inorganic forms, is a component of a number of different industrial processes and products, including the plastics industry, batteries, wood preservatives, fire retardants, and rodenticides (Bertholf 1988). Exposures to airborne zinc can occur near galvanizing, smelting, or foundry operations.

The toxicity of zinc is considered to be relatively low. Ingestion of excessive levels of zinc in humans may lead to nausea, vomiting, epigastric distress, and anemia. Intestinal hemorrhage and pancreatic alterations have been observed in animals fed high levels of zinc compounds (ATSDR 1988). Chronic oral exposures to zinc have resulted in certain anemias in humans, and limited evidence also suggests that the human immune system may be impaired by subchronic oral exposure to zinc (including zinc taken as a dietary supplement) (Opresko 1992).

Inhalation of high concentrations of zinc can cause metal fume fever, characterized by rapid breathing, shivering, fever, sweating, generalized weakness, and temporary impairment of pulmonary functioning, which has been observed in workers exposed to certain zinc vapors (Bertholf 1988; ATSDR 1988).

Oral exposure to high levels of zinc has been shown to reduce fetal growth rate and reduce reproductive success in exposed animals (ATSDR 1988; Opresko 1992). No epidemiologic data are available to evaluate the carcinogenicity of zinc in humans. Although two studies of ingestion of zinc placed in the food or water of mice resulted in no excess cancers, another longer-term study in mice observed increased tumor frequencies after exposure to zinc in water (Opresko 1992).

6.8.2 Organics

Benzo(*a*)anthracene (see toxicity profile for PAHs). Benzo(*a*)anthracene is a PAH and exhibits many of the characteristics of other PAHs. Because no substantial information about the toxicity of benzo(*a*)anthracene is available in the literature, the reader is referred to the toxicity profiles for the PAHs benzo(*a*)pyrene, benzo(*b*)fluoranthene, and indeno(1,2,3-*cd*)pyrene as well as the profile containing general information for PAHs.

Benzo(*a*)pyrene (see also toxicity profile for PAHs). Benzo(*a*)pyrene is a PAH that can be derived from coal tar. It occurs ubiquitously in products of incomplete combustion of fossil fuels and has been identified in ambient air, surface water, drinking water, waste water, and char-broiled foods. Benzo(*a*)pyrene is primarily released to the air and removed from the atmosphere by photochemical oxidation and dry deposition to land or water. Biodegradation is the most important transformation process in soil or sediment (BEIAS 1995).

Benzo(*a*)pyrene is readily absorbed after inhalation, ingestion, and dermal contact. After inhalation exposure, benzo(*a*)pyrene is rapidly distributed to several tissues in rats. The metabolism of the compound is complex and includes the formation of a proposed ultimate carcinogen, benzo(*a*)pyrene 7,8 diol-9,10-epoxide. The major route of excretion is hepatobiliary followed by elimination in the feces (BEIAS 1995).

Numerous epidemiologic studies have shown a clear association between exposure to various mixtures of PAHs containing benzo(*a*)pyrene (e.g., coke oven emissions, roofing tar emissions, and cigarette smoke) and increased risk of lung cancer and other tumors. However, each of the mixtures also contained other potentially carcinogenic PAHs; therefore, distinguishing the contribution of benzo(*a*)pyrene to the carcinogenicity of these mixtures is not possible. An extensive database is available for the carcinogenicity of benzo(*a*)pyrene in experimental animals. Dietary administration of the compound has produced papillomas and carcinomas of the forestomach in mice, and treatment by gavage has produced mammary tumors in rats and pulmonary adenomas in mice. Exposure by inhalation and intratracheal instillation has resulted in benign and malignant tumors of the respiratory and upper digestive tracts of hamsters. Numerous topical application studies have shown that benzo(*a*)pyrene induces skin tumors in several species, although mice appear to be the most sensitive species. Benzo(*a*)pyrene is a complete carcinogen and also an initiator of skin tumors. It has been reported to induce tumors in animals when administered by other routes, such as intravenous, intraperitoneal, subcutaneous, intrapulmonary, and transplacental. EPA has assigned benzo(*a*)pyrene to weight-of-evidence Group B2, probable human carcinogen (BEIAS 1995).

Benzo(*b*)fluoranthene (see also toxicity profile for PAHs). Benzo(*b*)fluoranthene, a crystalline solid with a chemical formula of $C_{20}H_{12}$ and a molecular weight of 252.32, is a PAH with one five-membered ring and four six-membered rings. No commercial production or use of this compound is known. Benzo(*b*)fluoranthene is found in fossil fuels and occurs ubiquitously in products of incomplete combustion. It has been detected in cigarette smoke, urban air, gasoline engine exhaust, emissions from burning coal and from oil-fired heating, broiled and smoked food, oils and margarine; and in soils, groundwater, and surface waters at hazardous waste sites (BEIAS 1995).

No absorption data were available for benzo(*b*)fluoranthene; however, by analogy to structurally related PAHs, primarily benzo(*a*)pyrene, it would be expected to be absorbed from the gastrointestinal tract, lungs, and skin. Major metabolites of benzo(*b*)fluoranthene formed in vitro in rat liver include dihydrodiols and monohydroxy derivatives and monohydroxy derivatives in mouse epidermis (BEIAS 1995).

No data about the acute, subchronic, chronic, developmental, or reproductive toxicity of benzo(*b*)fluoranthene were found, and no data for the derivation of an oral RfD or inhalation RfC were available. Because of the lack of human data and sufficient evidence for carcinogenicity in animals, EPA has assigned a weight-of-evidence classification of B2, probable human carcinogen, to benzo(*b*)fluoranthene (BEIAS 1995).

Benzo(*g,h,i*)perylene. See toxicity profile for PAHs.

Bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate is a colorless, oily liquid used extensively as a plasticizer in a wide variety of industrial, domestic, and medical products. An environmental contaminant, it has been detected in groundwater, surface water, drinking water, air, soil, plants, fish, and animals. It is rapidly absorbed from the gastrointestinal tract primarily as mono(2-ethylhexyl)phthalate. The diester can be absorbed through the skin and from the lungs. It is rapidly metabolized in the blood and tissues to the monoester, which can be excreted as a glucuronide conjugate, or further hydrolyzed to phthalic acid and excreted (BEIAS 1995).

Animal studies have indicated that the primary target organs are the liver and kidneys; however, higher doses are reported to result in testicular effects and decreased hemoglobin and packed cell volume. The primary intracellular effects of bis(2-ethylhexyl)phthalate in the liver and kidneys are an increase in the smooth endoplasmic reticulum and a proliferation in the number and size of peroxisomes. An epidemiologic study reported no toxic effects from occupational exposure to air concentrations of bis(2-ethylhexyl)phthalate up to 0.16 mg/m^3. Other studies on occupational exposures to mixtures of phthalate esters containing bis(2-ethylhexyl)phthalate have reported polyneuritis and sensory-motor polyneuropathy with decreased thrombocytes, leukocytes, and hemoglobin in some exposed workers. Developmental toxicity studies with rats and mice have shown that bis(2-ethylhexyl)phthalate is fetotoxic and teratogenic when given orally during gestation. Oral exposure has also been shown to result in decreased sperm count in rats (BEIAS 1995).

Chloroform. Chloroform, or trichloromethane, is a colorless, pleasant smelling chemical that is widely used in the production of pharmaceuticals, plastics, fluorocarbons, refrigerants, pesticides, dyes, and other solvents. Its past use as a general anesthetic has been discontinued because of its toxic effects.

Chloroform is rapidly absorbed from the lungs, gastrointestinal tract, and, to some extent, skin. Cases of occupational, accidental, and intentional exposure in humans and experimental studies in several animal species indicate that chloroform depresses the central nervous system, causes heart and liver effects, and may result in possible death (ATSDR 1989b; Torkelson and Rowe 1981). At lower concentrations, chloroform may cause irritability, gastrointestinal symptoms, and frequent, burning urination (Faust 1992). Kidney effects have been reported in rats and mice after oral and inhalation exposures, but the evidence in humans for these effects is sparse (EPA 1985; Faust 1992). Potential reproductive and developmental toxicity and possible

teratogenic effects are indicated in rodents exposed to chloroform by inhalation and ingestion, but no data on these effects in humans are available (ATSDR 1989b; Torkelson and Rowe 1981).

Epidemiological studies indicate a possible relationship between exposure to chloroform in chlorinated drinking water and cancers of the bladder, large intestine, and rectum (ATSDR 1989b; EPA 1985; Faust 1992); however, because chloroform was not the only contaminant in the drinking water, the excess cancer rate cannot be clearly attributed to chloroform. Orally administered chloroform has produced cancer of the liver and kidneys in mice and rats (IARC 1979; Faust 1992). The EPA has classified chloroform in Group B, probable human carcinogen (Faust 1992).

Cyclotrimethylenetrinitramine (RDX). This is a solid explosive chemical. This chemical is insoluble in water. Environmental studies and evaluation of the physicochemical properties of this compound conclude that when RDX is released to the environment, it is likely to reside in the subsurface soil (Layton et al. 1987). This chemical is used in the manufacturing of munitions.

RDX powder acts as an irritant when applied to the skin. Munitions workers have reported mild dermatitis, however, it is unknown if this was associated with exposure to RDX or trinitrotoluene (Layton et al. 1987). Acute RDX toxicity in humans is primarily manifested in the central nervous system. Specific neurotoxic symptoms in humans include hyperirritability, muscle twitching, generalized epileptiform seizures, and prolonged confusion and amnesia. Laboratory animals have shown similar symptoms (Layton et al. 1987). Exposure to RDX has been implicated in the increased incidence of systemic lupus erythematosus (SLE) at a munitions plant. However, epidemiological studies conducted at five munitions plants, did not show a statistically significant difference in the number of individuals tested for indicators of lupus (Layton et al. 1987).

Chronic toxicity studies with rodents have identified reproductive and developmental toxicity as the most sensitive toxicity endpoints. RDX has been classified as a Class C carcinogen for oral exposure (EPA 1997c).

Dibenzo(*a,h*)anthracene (see also toxicity profile for PAHs). Dibenzo(*a,h*)anthracene is a PAH with five aromatic rings that occurs as a component of coal tars, shale oils, and soots. It has been detected in gasoline engine exhaust, coke oven emissions, cigarette smoke, charcoal-broiled meats, vegetation near heavily traveled roads, and surface water and soils near hazardous waste sites. No commercial production or use of dibenzo(*a,h*)anthracene is known (BEIAS 1995).
Dibenzo(*a,h*)anthracene is poorly absorbed from the gastrointestinal tract and is primarily excreted via feces. After absorption, it is distributed to various tissues, with highest accumulation in the liver and kidneys. Dibenzo(*a,h*)anthracene is metabolized by mixed-function oxidases to dihydrodiols. Epoxidation of the 3,4-dihydrodiol may lead to the formation of a diolepoxide, the putative ultimate carcinogenic metabolite of dibenzo(*a,h*)anthracene (BEIAS 1995).

The EPA has derived no oral RfD or inhalation RfC for dibenzo(*a,h*)anthracene. In addition, no epidemiologic studies or case reports of the carcinogenicity of the compound in humans are available. In animals, dibenzo(*a,h*)anthracene administered by different routes has produced tumors, showing both local and systemic carcinogenic effects (BEIAS 1995).

HMX. See toxicity profile for Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine.

Indeno(1,2,3-*cd*)pyrene (see also toxicity profile for PAHs). Indeno(1,2,3-*cd*)pyrene, a crystalline solid with a chemical formula of $C_{22}H_{12}$ and a molecular weight of 276.3, is a PAH. It is found in fossil fuels, occurs ubiquitously in products of incomplete combustion, and has been identified in soils, groundwater, and surface waters at hazardous waste sites. No commercial production or use of this compound is known.

No absorption data for indeno(1,2,3-*cd*)pyrene were available; however, analogy to structurally related PAHs, primarily benzo(*a*)pyrene, suggests that it would be absorbed from the gastrointestinal tract, lungs, and skin. In vivo metabolites identified in mouse skin include the *trans*-1,2-dihydrodiol and 8- and 9-hydroxy forms of indeno(1,2,3-*cd*)pyrene. Similar metabolites were formed in vitro in rat liver microsomes.

No data on the acute, subchronic, chronic, developmental, or reproductive toxicity of indeno(1,2,3-*cd*)pyrene were found. Because of a lack of toxicity data, no oral RfD or inhalation RfC has been derived. EPA has assigned indeno(1,2,3-*cd*)pyrene to a weight-of-evidence classification of B2, probable human carcinogen.

2-Methylnaphthalene. See toxicity profile for Methylnaphthalene.

Methylnaphthalene (see also toxicity profile for PAHs). Methylnaphthalene is a PAH and exhibits many of the characteristics or other PAHs. There are limited data concerning the toxicity of this compound. Inhalation of the vapors may produce airway irritation, headache, nausea, weakness, and unconsciousness. Long-term overexposure has led to corneal changes. Ingestion may lead to systemic poisoning involving the gastrointestinal tract, kidneys, and hematopietic system (NTP 1998).

Data located regarding the noncancer toxicity of methylnaphthalene are limited to an oral lowest dose associated with lethality (LD_{LO}) in rats of 5000 mg/kg (Sax 1984). No data concerning the carcinogenicity of this compound was found in the literature.

Nitrocellulose as N. No toxicity profile could be found for Nitrocellulose as N.

Nitroglycerin. Nitroglycerin is a pale yellow liquid or crystalline solid. It is used in making dynamite, other explosives, rocket propellants and medicine. It may enter the environment from industrial discharges, from dynamite operations, or spills (EPA 1998c).

Nitroglycerin is extremely soluble in water. If nitroglycerin is released to the environment, approximately 99.8 percent will eventually end up in water; the rest will end up in about equal amounts in terrestrial soils and in aquatic sediment (EPA 1998c).

Acute exposures to nitroglycerin can cause severe throbbing headache, nausea, and a fall in blood pressure resulting in dizzy spells. Higher exposure can cause vomiting, abdominal pain, methemoglobinemial (red blood cell hemolysis), and possible coma or death (EPA 1998c). The primary target organ system is the circulatory system where it may cause vasodilatation leading to a fall in blood pressure and methemoglobinemial (EPA 1998c).

Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). HMX is a solid white crystalline solid, which is explosive. Environmental studies and evaluation of the physicochemical properties of this compound conclude that when HMX is released to the environment, it is likely to reside in the subsurface soil and groundwater (Layton et al. 1987). This chemical is used in the manufacturing of munitions.

An unusually high incidence of SLE at a munitions plant led to an epidemiological study to determine if there is a correlation of SLE and exposure to explosives. Workers were exposed to HMX, or to HMX in combination with TNT and/or TNT. However, no analysis of HMX concentrations in the air was conducted. The study concluded that there was no statistically significant evidence linking SLE with exposure to explosives (Layton et al. 1987). Another study evaluated the ability of solid HMX to induce hypersensitivity reactions in occupationally exposed individuals. The study reported a positive response in some individuals; however, animal studies have not shown that HMX may cause an allergic response (Layton et al. 1987).

Subchronic toxicity studies with rodents have identified acceptable oral exposure concentrations. The liver has been identified as the primary target organ for oral toxicity (EPA 1998a).

Phenanthrene. See toxicity profile for Noncarcinogenic PAHs.

Polycyclic aromatic hydrocarbons. The PAHs are a group of chemicals that are formed during the incomplete burning of wood and fuel, including coal, oil, gas, and other organic substances (ATSDR 1989c). Exposure to PAHs may occur via inhalation, ingestion, and dermal contact. In any medium, PAHs most often exist as complex mixtures of compounds, and these compounds have been divided into (1) carcinogenic PAHs and (2) noncarcinogenic PAHs.

Carcinogenic polycyclic aromatic hydrocarbons. Available data indicate that benzo(*a*)pyrene is one of the most potent of the carcinogenic PAHs. Other PAHs considered to be carcinogenic are benzo(*a*)anthracene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, chrysene, dibenzo(*a,h*)anthracene, and indeno(1,2,3-*cd*)pyrene.

The arrangement of aromatic rings in the benzo(*a*)pyrene molecule and other PAHs gives it a bay-region that is often correlated with carcinogenic properties. In general, bay-region PAHs and some of their metabolites are known to react with cellular macromolecules, including DNA, which may account for the toxicity and carcinogenicity of these compounds (Francis 1992). The primary toxicological concern about exposure to this group of PAHs is carcinogenicity. No case reports or epidemiological studies on the significance of human exposure to individual PAHs are available. Coal tar and other materials known to be carcinogenic to humans, however, contain PAHs (Francis 1992). Lung and skin cancers in humans have been associated with chronic exposure by inhalation and dermal contact, respectively, to mixtures of compounds that include carcinogenic PAHs (ATSDR 1989c). Several individual PAHs administered to different animal species by various routes have been found to be carcinogenic at both local and systemic sites. Long-term experimental studies resulted in tumors in the liver, mammary gland, respiratory and gastrointestinal tracts, and skin (ATSDR 1989c). Carcinogenic PAHs are also reported to be mutagenic in a variety of test systems.

Although reproductive effects in mice fed benzo(*a*)pyrene and adverse effects in their offspring, including birth defects and decreased body weight, have been reported, no reproductive toxicity from PAH exposure has been demonstrated in humans (ATSDR 1989c). Toxic effects have also been observed in rapidly dividing cells of the intestinal epithelium, testes, and ovaries (oocytes). Animal studies also indicate that exposure to bay-region PAHs can damage the hematopoietic system, leading to progressive anemia as well as agranulocytosis. The lymphoid system can also be affected, resulting in lymphopenia.

Not all of the carcinogenic PAHs appear to be as potent as benzo(*a*)pyrene (ICF-Clement 1988; EPA 1993a). Recent guidance published by EPA (1993a) recommended that a series of relative potency values (orders of magnitude) be used for the risk assessment of oral exposure to PAHs, with carcinogenic potency being compared to that of benzo(*a*)pyrene.

Noncarcinogenic polycyclic aromatic hydrocarbons. PAHs not considered to be carcinogenic include acenaphthene, benzo(*g,h,i*)perylene, naphthalene, and phenanthrene.

PAHs are toxic to the skin. For example, naphthalene is a primary skin irritant and causes erythema and dermatitis on repeated contact (Sittig 1981), and acenaphthene is irritating to the skin and mucous membranes of humans and animals (Faust 1994). Other noncarcinogenic effects of PAHs have been observed in animals; however, of these, only effects of the blood and blood-forming system and of the skin have also been reported in humans (ATSDR 1989c). Animal studies indicate that PAHs may adversely affect the gastrointestinal tract, liver, kidneys, lungs, and hematopoietic system and may suppress the immune system after both short- and long-term exposure. Oral exposure of animals to acenaphthene caused reproductive effects, including

decreased ovary weights, decreased ovarian and uterine activity, and fewer and smaller corpora lutea (Faust 1991, 1994). No mutagenic or carcinogenic effects of the noncarcinogenic PAHs have been reported.

RDX. See toxicity profile for Cyclotrimethylenetrinitramine.

1, 3, 5 -Trinitrobenzene. TNB is a slightly yellow crystal. This compound is a by-product of TNT production and TNT phytolysis. This chemical is likely to be present in the environment in areas where TNT has been released. It is water soluble and is likely to primarily reside in the groundwater and vadose zone under steady-state conditions (Layton et al. 1987).

Toxicological data on TNB are limited, ostensibly because this chemical was never commercially produced and, thus, there are no occupational health issues to prompt toxicological or epidemiological investigations.

Animal studies indicate that the hematopietic system and the testes are the primary target organs. The critical hematopietic effects noted include methemoglobinemia and spleen-erythroid cell hyperplasia. Degeneration of the testes has also been noted in rats (EPA 1998a).

2, 4, 6 - Trinitrotoluene. TNT is a yellow to colorless crystalline sold. It is used to make explosives and as a chemical intermediate in the manufacture of dyestuffs and photographic chemicals. TNT is likely to enter the environment in wastewater effluents from production facilities and from leachates at waste disposal sites. Mobility in soil may be limited by strong adsorption to soil particles (BEIAS 1995).

Occupations exposure studies indicate that the major effects of chronic exposure to TNT include anemia (decreases in Hgb, Hct, and RBC count), liver dysfunction (increases in serum lactic dehdrogenase, glutamic oxaloacetic transaminase, and bilirubin), and cataracts (equatorial lens opacities). Other reported effects of TNT exposure include dermatitis, leukocytosis, neurological disorders, and nephrotoxicity (BEIAS 1995).

The primary target organs for TNT toxicity in laboratory animals are (1) liver (hepatocytomegaly and cirrhosis), (2) blood (hemolytic anemia with secondary alterations in the spleen), (3) testes (degeneration of the germinal epithelium lining the seminiferous tubules (BEAIS 1995). The liver has been identified as the most sensitive organ system (EPA 1998a).

EPA has classified TNT as a Class C carcinogen (EPA 1998a).

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