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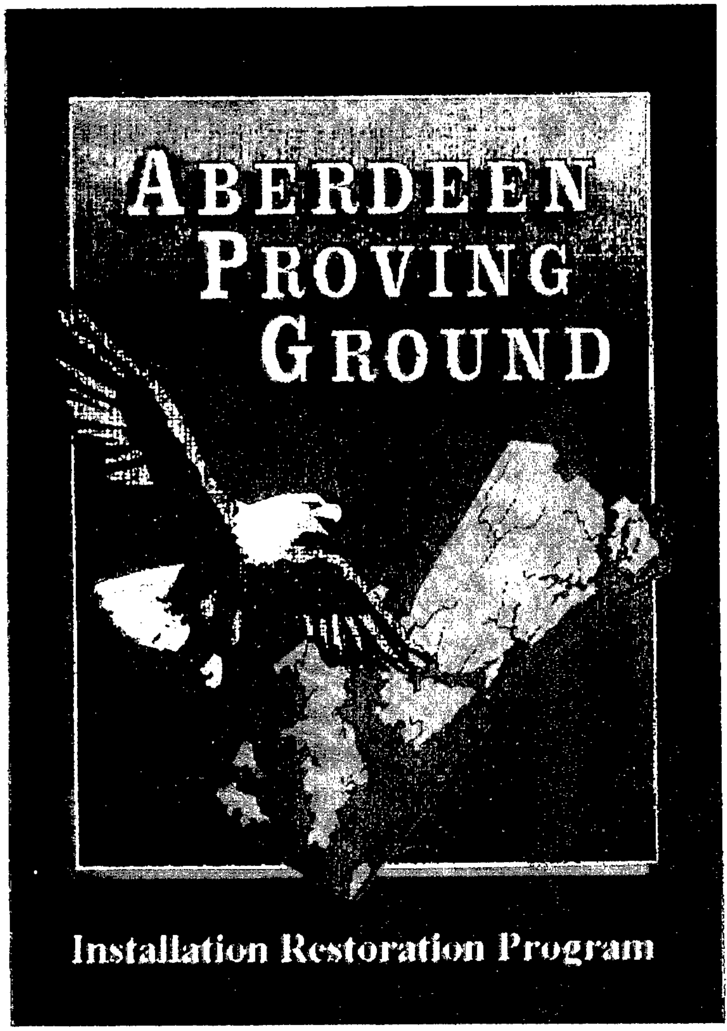

DEPARTMENT OF THE ARMY UNITED STATES OF AMERICA

PRELIMINARY RISK ASSESSMENT FOR EIGHT SELECTED STUDY AREAS
VOLUME I

FINAL DOCUMENT

Aberdeen Proving Ground, Maryland

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This report presents preliminary baseline risk assessments for eight priority areas of known or suspected chemical contamination at Aberdeen Proving Ground (APG), Maryland. The eight priority areas were selected by the U.S. Army based on past activities at APG and environmental sampling data and have been identified as areas of concern in the Interagency Agreement (IAG) for remediation that has been negotiated between the Army and EPA Region III. These risk assessments provide information on potential adverse effects on humans and wildlife from chemical contamination at these sites under existing conditions (i.e., in the absence of further remedial actions). They are considered to be preliminary estimates of risk due to data limitations and are considered to be most useful for identifying the chemicals, exposure pathways, populations of greatest potential concern for each area so that subsequent studies, investigation, and cleanup measures can be focused. These eight sites were prioritized according to the need for further action.

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PRELIMINARY RISK ASSESSMENT FOR EIGHT SELECTED STUDY AREAS AT ABERDEEN PROVING GROUND, MARYLAND

VOLUMES I AND II

FINAL DOCUMENT

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ACRONYMS AND ABBREVIATIONS

AC:	Hydrogen cyanide
AEHA:	U.S. Army Environmental Health Agency
AMBRDL:	U.S. Army Medical Bioengineering Research and Development Laboratory, Fort Detrick, Frederick, MD
APG:	Aberdeen Proving Ground
APG-AA:	Aberdeen Proving Ground-Aberdeen Area
APG-EA:	Aberdeen Proving Ground-Edgewood Area
BBC:	An irritant (bromobenzyl cyanide), also known as CA
Bis:	A simulant (bis-2-ethylhexyl hydrogen phosphite)
BHC:	Benzenehexachloride
BOD:	Biological oxygen demand
BZ:	An incapacitating agent (3-quinuclidinyl benzilate)
CC2:	s-bis(2,4,6-trichlorophenylchlor)urea, sym-dichloro-bis(2,4,6-trichlorophenyl)urea or N,N'-dichloro-bis(2,4,6-trichlorophenyl)urea
CDA:	Diphenyl cyanoarsine
CG:	Phosgene
CK:	Cyanogen chloride, blood agent
CN:	Tear gas, a riot control agent (chloroacetophenone)
CN:	Cyanide
CNB:	An agent mixture of 10% CN, 45% benzene, and 45% carbon tetrachloride
CNS:	A mixture of chloroacetophenone, chloropicrin, and chloroform
COD:	Chemical oxygen demand
COE:	U.S. Army Corps of Engineers
CRDEC:	U.S. Army Chemical Research Development and Engineering Center
CS:	Tear gas, a riot control agent (O-chlorobenzylidene malononitrile)
CS-1:	CS blended with 5-percent silica aerogel
CS-2:	CS blended with a hydrophoric compound
2,4-D:	2,4-Dichlorophenoxyacetic acid, an herbicide
DA:	Diphenyl chloroarsine
DANC:	Decontaminating Agent, noncorrosive; an organic-based decontaminant
DBHP:	A simulant (dibutyl hydrogen phosphite)
DDD:	Dichlorodiphenyldichloroethane, similar to DDT, also known as tetrachlorodiphenylethane, TDE, and 1,1-dichloro-2,2-bis(parachlorophenyl)ethane
4,4-DDD:	See DDD
DDE:	Dichlorodiphenyldichloroethene, a degradation product of DDT
4,4'-DDE:	See DDE
DDT:	Dichlorodiphenyltrichloroethane, an insecticide
4,4'-DDT:	See DDT
DEHP:	A simulant (chemical name not available; possibly Diethyl hydrogen phosphite)
DM:	Adamsite, a vomiting agent (diphenylamino-chloroarsine)
DMHP:	A simulant (dimethyl hydrogen phosphite)
1,3-DNB:	1,3-Dinitrobenzene, used in organic synthesis of dyes and munitions
2,4-DNT:	2,4-Dinitrotoluene, an explosive
2,6-DNT:	2,6-Dinitrotoluene, an explosive
DO:	Dissolved oxygen
DPU:	Sym-diphenylurea
DS-2:	An organic-based decontaminant, contains 70% diethylenetriamine, 28% 2-methoxyethanol, and 2% sodium hydroxide
EA 1356:	An organophosphorus nerve agent

ACRONYMS AND ABBREVIATIONS
(Continued)

EA 3834:	An incapacitating agent (no common or chemical name available)
EA 3528:	An incapacitating agent (no common or chemical name available)
EA 3990:	A nerve agent (no common or chemical name available)
EDA:	A simulant (ethylenediamine)
EPG:	Edgewood Proving Ground, an organization which operated for a period in the 1940's or 1950;'s and was later incorporated into Edgewood Arsenal
EPA:	U.S. Environmental Protection Agency
FEMA:	Federal Emergency Management Agency
FM:	Titanium tetrachloride
FS:	A screening smoke (Sulfur trioxide and chlorosulfonic acid)
GA:	The nerve agent Tabun (ethyl N, N-dimethyl phosphoroamidocyanidate)
GB:	The nerve agent Sarin (isopropyl methyl phosphonofluoridate)
GC/MS:	Gas chromatography/mass spectometry
GD:	The nerve agent Soman (pinacolyl methyl phosphonofluoridate)
H:	Mustard
HC:	Smoke mixtures containing hexachloroethane
HCA:	Hexachloroethane
HCN:	Hydrogen cyanide, a hydrolysis product of G-type agents
HD:	Distilled mustard, a blister agent (bis[2-chloroethyl]sulfide)
HE:	High explosive
HF:	Hydrogen fluoride, a hydrolysis product of G-type agents
HGA:	Hydrogeologic Assessment
HMX:	Cyclotetramethylenetetranitramine, a munition
HTH:	Calcium hypochlorite, used as a chemical decontaminant
IMPA:	Isopropylmethyl phosphonic acid
IRFMA:	Inhibited red fuming nitric acid
L:	Lewisite
LC_{50}:	Median lethal concentration
LEL:	Lower explosive limit
LO:	Lewisite oxide
MCL:	Maximum Contaminant Level
MIPK:	Methyl isopropyl ketone
NO_2:	Nitrite
NO_3:	Nitrate
1,1,1,2-PCA:	1,1,1,2-Tetrachloroethane
PAH:	Polycyclicaromatic hydrocarbon
PCB:	Polychlorinated biphenyls
PETN:	Pentaerythritol tetranitrate
PPE:	Personal protective equipment
PS:	Chloropicrin
PVC:	Polyvinyl chloride, a plastic
PWP:	Plasticized white phosphorus
RCRA:	Resource Conservation and Recovery Act
RDX:	Cyclonite/Hexahydro-1,3,5-trinitro-1,3,4-triazine, a munition
RFA:	RCRA Facility Assessment
RFI:	RCRA Facility Investigation
SO_4:	Sulfate
STB:	Supertropical bleach, a chemical decontaminant

ACRONYMS AND ABBREVIATIONS
(Continued)

SW:	Methyl dichloro-phosphine
SWMU:	Solid Waste Management Unit
2,4,5-T:	2,4,5-Trichlorophenoxyacetic acid, an herbicide
TCA:	2,4,6-Trichloroaniline
TCPU:	sym-bis(2,4,6-trichlorophenyl)urea, an intermediate in the production of CC2
TDS:	Total dissolved solids
TEA:	A simulant (triethyl aluminum)
Tec Escort:	See USTEU
TEP:	EP tox procedure
TEU:	See USTEU
TIC:	Tentatively identified compounds, compounds identified during a library search of mass spectra
1,2,3-TNB:	1,2,3-Trinitrobenzene
TNB:	1,3,5-Trinitrobenzene
TNT:	2,4,6-Trinitrotoluene, an explosive
TOC:	Total organic carbon
TOF:	A simulant (tri[2-ethylhexyl]phosphate)
TOX:	Total organic halogen
TSS:	Total suspended solids
UDMH:	Unsymmetric dimethyl hydrazine
USATHAMA:	U.S. Army Toxic and Hazardous Materials Agency
USAEHA:	see AEHA
USGS:	United States Geological Survey
USTEU:	U.S. Army Technical Escort Unit
UXO:	Unexploded ordnance
VOC:	Volatile organic compounds
VX:	A nerve agent (b-diisopropylaminoethyl-mercapto-O-ethyl methyl-phosphonothioate)
WP:	White phosphorus, a screening smoke or incendiary
XXCC3:	CC2 mixed with zinc oxide

CHEMICAL ELEMENT ABBREVIATIONS

Al: Aluminum
Sb: Antimony
As: Arsenic
Ba: Barium
Be: Beryllium
Br: Bromine
Cd: Cadmium
Ca: Calcium
Cl: Chlorine
Cr: Chromium
Cu: Copper
Fe: Iron
Pb: Lead
Mg: Magnesium
Mn: Manganese
Hg: Mercury
Ni: Nickel
P: Phosphorus
K: Potassium
Se: Selenium
Na: Sodium
Si: Silicon
Ag: Silver
S: Sulfur
Tl: Thallium
Zn: Zinc

1.0 INTRODUCTION

This report presents baseline risk assessments for eight priority areas of known or suspected chemical contamination at Aberdeen Proving Ground (APG), Maryland. The report provides information on potential adverse effects to human and ecological receptors associated with chemical contamination at these sites under no-action (i.e., baseline) conditions. ICF Kaiser Engineers (ICF KE) and Clement International Corporation (Clement) have prepared this baseline risk assessment under Task Order 11 of Contract DAAA15-87-009.

The eight priority areas have been identified through review of historical records and environmental sampling by the U.S. Army and its contractors, and have been identified as areas of concern in the Interagency Agreement (IAG) for remediation that has been negotiated between the Army and EPA-Region 3.[1] The eight priority areas are as follows:

- O-Field - a former test range and ordnance disposal area that includes a chemical munitions/hazardous waste landfill and several open-burning pits that were used for the disposal of chemical agents and other hazardous materials;
- J-Field - an open burning/open detonation (OB/OD) area used for disposal of toxic chemical agents, white phosphorus, and organic solvents;
- Canal Creek - a watershed (including extensive wetlands) that encompasses the majority of APG's former chemical agent, smoke/incendiary, and protective-clothing manufacturing operations, and includes more than 30 potential contamination source areas;
- Carroll Island - a former test range used for open-air testing of nerve agents, incapacitating agents (e.g., tear agents), and smoke and incendiary munitions; several former open-burning areas, test sites, and possible disposal pits have been identified in this area;
- Graces Quarters - an additional open-air testing area for munitions and chemical agents that also contains several potential hazardous waste burial pits and open-burning areas;
- Nike Site - the location of school fields used by the U.S. Army Chemical School for training in chemical warfare activities and a former Nike Ajax and Hercules ballistic missile site (including launch and control areas) that contains areas of suspected waste disposal, leaking fuel storage tanks, and known groundwater contamination;
- Michaelsville Landfill - a sanitary landfill suspected to contain paint sludges, metals, pesticides, PCBs, and other hazardous wastes; and

---

[1] The IAG divides APG into 13 areas of concern to be addressed under the CERCLA remedial action program. These 13 areas encompass more than 700 potential sources of contamination (or solid waste management units [SWMUs]) previously identified under the facility's RCRA corrective action program. The areas of concern that are not addressed in this baseline risk assessment: (1) Westwood; (2) Bush River Areas; (3) other Edgewood Areas; (4) other Aberdeen Areas; and (5) White Phosphorus Disposal Area.

- Phillips Army Airfield Study Area - an area that includes a sanitary/construction-debris landfill and several other potential disposal sites, including open-burning areas and "grease pits" used for disposal of food wastes, petroleum products, and transformer fluids containing PCBs.

The first six of the above-mentioned sites are located within the Edgewood Area of APG (formerly known as Edgewood Arsenal), which encompasses the Gunpowder Neck peninsula and the Carroll Island/Graces Quarters areas. Michaelsville Landfill and the Phillips Army Airfield Study Area are located in the Aberdeen Area of APG.

1.1 PURPOSE AND SCOPE

The baseline risk assessments are intended to evaluate potential risks to human and ecological receptors resulting from chemical contamination at the eight priority sites outlined above, under baseline or no-action conditions (i.e., in the absence of any remediation, including active cleanup measures and any institutional/access controls other than those that are in place at the present time). The risk assessments are intended to meet the requirements of the National Contingency Plan (NCP) (EPA 1990) for the evaluation of baseline conditions at uncontrolled hazardous waste sites, and have been performed according to the most recent EPA guidance regarding human health and ecological assessments.

The purpose of the baseline risk assessments is to identify the chemicals of concern, principal exposure pathways, and receptors of greatest potential concern at each of the sites and to characterize risks. Risks will be quantified, if possible, for pathways and receptors of potential concern, so that the need for remediation can be determined, and, if necessary, site-specific targets for remediation can be established. With the very large number of potential contamination sources, complex environmental settings, and wide variety of hazardous chemicals present at APG, another important feature of the baseline risk assessments is that they also may be used qualitatively to identify the site conditions (chemicals, exposure pathways, receptors) of greatest potential concern, so that subsequent studies, investigations, and cleanup measures can be focused in these areas. This aspect of the risk assessment is considered especially critical for APG, in that more than 700 individual areas that may represent potential contamination sources have been identified and overall cleanup costs are likely to be extremely high. Therefore, a generally applicable and consistent methodology based on scientific principles is required to ensure that limited resources are focused in areas where risks are most severe and remediation efforts are likely to provide the greatest overall benefits.

The scope of the APG baseline risk assessments is broad compared to many no-action evaluations at Superfund sites, mainly because of the highly complex disposal site characteristics and environmental settings at the installation. The following risk scenarios have been included in our analysis:

- Chronic human health risks related to chemical exposures based on both carcinogenic and noncarcinogenic effects;

- Acute and chronic risks to aquatic receptors, including benthic organisms, species at the primary productivity level, and free-swimming species at all trophic levels (including population effects);

- A limited evaluation of possible risks to terrestrial species related to direct or food-chain exposures to site chemicals; and

- Potential acute risks to human and ecological receptors related to catastrophic events (e.g., spontaneous detonation of chemical agent-filled munitions) that could occur at some sites (e.g., Old O-Field).

Although the risk assessments address a wide range of potential adverse effects, it should be stressed that they are based in most instances on limited and incomplete chemical data and site characterization information, and are therefore subject to many limitations and uncertainties. Thus, the baseline risk assessments are intended primarily as an initial step in the overall risk assessment process at APG, with subsequent efforts to be focused on direct methods for evaluating adverse effects (e.g., biota sampling bioassays, population studies). Specific limitations related to the baseline assessments are outlined in the following subsection.

1.2 LIMITATIONS

The baseline risk assessments presented in this report are based entirely on existing data for the eight priority areas, gathered during hydrogeologic assessments (HGAs), RCRA facility assessments (RFAs), and other investigations conducted by the APG Directorate of Safety, Health, and Environment (APG-DSHE), U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), U.S. Army Environmental Hygiene Agency (USAEHA), U.S. Army Corps of Engineers-Waterways Experiment Station (WES), U.S. Geological Survey (USGS), and private contractors employed by these agencies. No environmental sampling has been conducted directly in support of this risk assessment by ICF KE, Clement, or any of the agencies mentioned above.

The reliance on existing data has limited the baseline risk assessments to some extent in that exposure pathways at most sites tend to be complex, involving contaminant migration and transport across several environmental media to a potential exposure point (e.g., groundwater transport to surface water, resulting in exposure of aquatic organisms), and complete data to evaluate these complex pathways is often lacking. For example, sites for which HGAs have been conducted typically have extensive groundwater data but are lacking adequate surface water to evaluate contaminated groundwater discharge to nearby surface water bodies and wetlands (a common feature of many APG sites). Evaluation of risks based on limited surface water data introduces considerable uncertainty into the estimates of risk.

Several additional factors associated with data adequacy and completeness limit the baseline risk assessments. These factors include the following:

- Chemical data used in the baseline risk assessments have been gathered by numerous agencies using widely varying analytical methods and quality assurance protocols. Moreover, data have not been compiled and stored in a consistent format; therefore, much of the original quality of some data sets resulting from the analysis of trip blanks, matrix spike, and other QA samples has been lost. The data quality and reliability varies widely from one area to another, which in turn contributes greatly to the uncertainty of risk assessment conclusions reached for some areas (This problem is discussed in much greater detail in Chapter 3 of this report -- Data Sources, Data Management, and Quality Assurance).

- Chemical analyses have not completely addressed the full range of contaminants that may be present in nearly all areas. This problem is especially difficult at the Edgewood Area sites, where a very wide variety of military-unique compounds related to the production of chemical agents, munitions, smoke, and incendiary materials may be present. Analyses for these types of compounds, which include (1) chemical agent degradation products such as thiodiglycol and di-isopropylmethylphosphonic acid (DIMP), (2) clothing-impregnating compounds such a bis-(2,4,6-trichlorophenyl)urea (TCPU), and (3) explosive propellant compounds such as RDX and HMX, are very limited or completely lacking for most areas. Without additional analyses for these compounds, it is difficult or impossible to fully evaluate potential risks at many sites.

- Many sites at APG are located in complex environmental settings that encompass tidal wetlands and ponds and other surface water bodies (including small creeks, larger streams, and major rivers), near-shore estuarine environments, and sensitive wildlife habitat. Many of these important environmental features are influenced significantly by short-term physical changes that occur regularly (e.g., diurnal tidal cycles) and irregularly (seasonal variations in precipitation, storm events). These events may result in large-scale variations in chemical conditions at potential exposure points as a result of dilution, flushing, or changes in groundwater-surface water relationships; in addition, short-term transport mechanisms such as surface runoff, sediment resuspension, and increased groundwater migration rates may result in greatly increased contaminant loading over short time periods. These intermittent "event" situations could potentially result in greatly increased risks at some sites, but cannot be evaluated based on current data because of the lack of a time-equivalent data set for these areas.

- Background data that can be used to evaluate naturally occurring levels of metals in soils, sediment, and water, as well as contributions of contaminants from sources outside the study area, are lacking for most environmental media at many of the eight priority sites. The lack of background data greatly affects the ability to positively identify risks attributable to site-related contamination, and to differentiate between impacts that may be caused by contamination from APG sites versus regional problems related to water-quality degradation in the Upper Chesapeake Bay system.

- The quantity of information and overall completeness of the data set varies widely among the sites being considered in the baseline risk assessments. Some site data bases include chemical analysis data for nearly the full range of environmental media (e.g., groundwater, surface water, soil, and sediment) whereas other sites have very limited data for only one medium. An example of the former type of site is O-Field, while Phillips Army Airfield is an example of the latter (limited groundwater data [VOCs and metals] from a small number of monitoring wells). Despite the availability of large quantities of data for some sites, no single site is considered to have a complete data base with respect to the chemical contaminants or the environmental media sampled.

Because of these major limitations, we believe that the baseline risk assessments should be considered preliminary. They are most useful for (1) focusing additional efforts on chemicals, exposure pathways, and receptors of greatest potential concern; and (2) directing subsequent studies toward important data gaps (e.g., chemical analysis needs, background characterizations) that need to be filled to evaluate risks more fully; and (3) providing a preliminary framework for ranking major

APG sites using a risk-based approach (rather than perceived threat), so that appropriate decisions regarding remediation priorities can be made.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this report is organized into 13 chapters:

- **Chapter 2: Overview of Aberdeen Proving Ground** provides background information on APG with respect to physical and environmental setting, site history, and land use.
- **Chapter 3: Data Sources, Data Management, and Quality Assurance** provides an overview of the sources of chemical sampling data for each of the eight study areas and discusses the data quality and reliability of the data used in these baseline risk assessments.
- **Chapter 4: Baseline Risk Assessment Methodology** describes the general methodology used to characterize human health and ecological risks at each of the eight study areas.
- **Chapters 5 - 12** are the baseline risk assessments for each study area. Each risk assessment contains (1) a summary of background information for the study area being evaluated, (2) an evaluation of chemical sampling data and selection of chemicals for evaluation in the risk assessment, (3) a human health risk assessment, (4) an ecological risk assessment, (5) the principal uncertainties associated with the risk estimates, and (6) identification of additional data needed for a more complete evaluation of the predicted risks.
- **Chapter 13: Base-wide Risk Assessment** qualitatively evaluates the cumulative ecological impacts of all eight study areas.
- **Chapter 14: Summary and Conclusions** provides brief synopses of the principal results of each risk assessment and highlights the primary risk assessment data needs. Finally, individual study areas are prioritized for further study based on the degree of risks each poses and the completeness of the available data base.

Appendices A through E provide supporting technical information for the baseline risk assessments. The appendices provide information on the fate and transport models used to estimate exposure concentrations (Appendix A), human health toxicity of the chemicals of concern at APG (Appendix B), ecological toxicity of the chemicals of concern at APG (Appendix C), the ecology of key receptor species (Appendix D), and the species likely to be present at APG (Appendix E).

1.4 REFERENCES

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1990. National oil and hazardous substances pollution contingency plan. Fed. Reg. 55:8666-8865 (March 8, 1990).

2.0 OVERVIEW OF ABERDEEN PROVING GROUND

This chapter provides a general overview of the Aberdeen Proving Ground with respect to its location, history, current mission and land use, ecology, geology, hydrology and water use, and meteorology.

2.1 LOCATION

Aberdeen Proving Ground (APG) is located in Maryland in southern Harford County and southeastern Baltimore County on the western shore of the upper Chesapeake Bay (see Figure 2-1). It is bordered to the east and south by the Chesapeake Bay; to the west by Gunpowder Falls State Park, the Tipple Power Plant and residential areas; and to the north by the towns of Edgewood, Magnolia, Aberdeen, and Perryman.

The installation is divided into two principal areas: the Edgewood Area (APG-EA) and the Aberdeen Area (APG-AA). Six of the study areas being evaluated in this assessment are located in the Edgewood area and two are located in the Aberdeen Area. Figure 2-2 shows the location of the eight study areas included in this assessment.

2.2 SITE HISTORY

APG was established in 1917 as the Ordnance Proving Ground and was designated a formal military post in 1919. Testing of ammunition and materiel and operation of training schools began at APG in 1918. Prior to World War II, activities at APG were characterized by intense research and development, and large-scale testing of a wide variety of munitions, weapons, and materiel. Just before and during World War II, the pace of weapons, munitions, and materiel testing increased greatly. During the war, personnel strength at APG exceeded 30,000. Similar but smaller-scale increases in munitions and materiel development and testing activities at APG were experienced during the Korean and Vietnam conflicts.

Most of the military chemical warfare research, development, and related activities at APG occurred in the Edgewood area. Specific activities at Edgewood include lab research, field testing of chemical materiel and munitions, pilot-scale manufacturing, and production-scale chemical agent manufacturing. Edgewood has also been a center for the storage of chemical warfare materiel and a major receiving center for waste handling operations including low-level radiological waste.

The Aberdeen area was historically used as a testing area for weapons, aircraft, and other equipment. Ammunitions testing for a wide variety of weapons has occurred at the Aberdeen area since 1919. The types of munitions tested include bombs, small arms projectiles, rockets, high-explosive (HE) ammunition, armor defeating grenades, antipersonnel mines and weapons, and incendiary and smoke grenades.

2.3 CURRENT MISSION AND LAND USE

APG's primary mission continues to be the testing and development of weapons, munitions, vehicles, and a wide variety of support materiel relevant to military operations. Currently, APG houses 13 Army organizations including the U.S. Army Ordnance Center and School (USAOC&S), the Chemical Research, Development and Engineering Center (CRDEC), the Army Environmental Hygiene Agency

Figure 2-1

Aberdeen Proving Ground, Edgewood and Aberdeen Areas

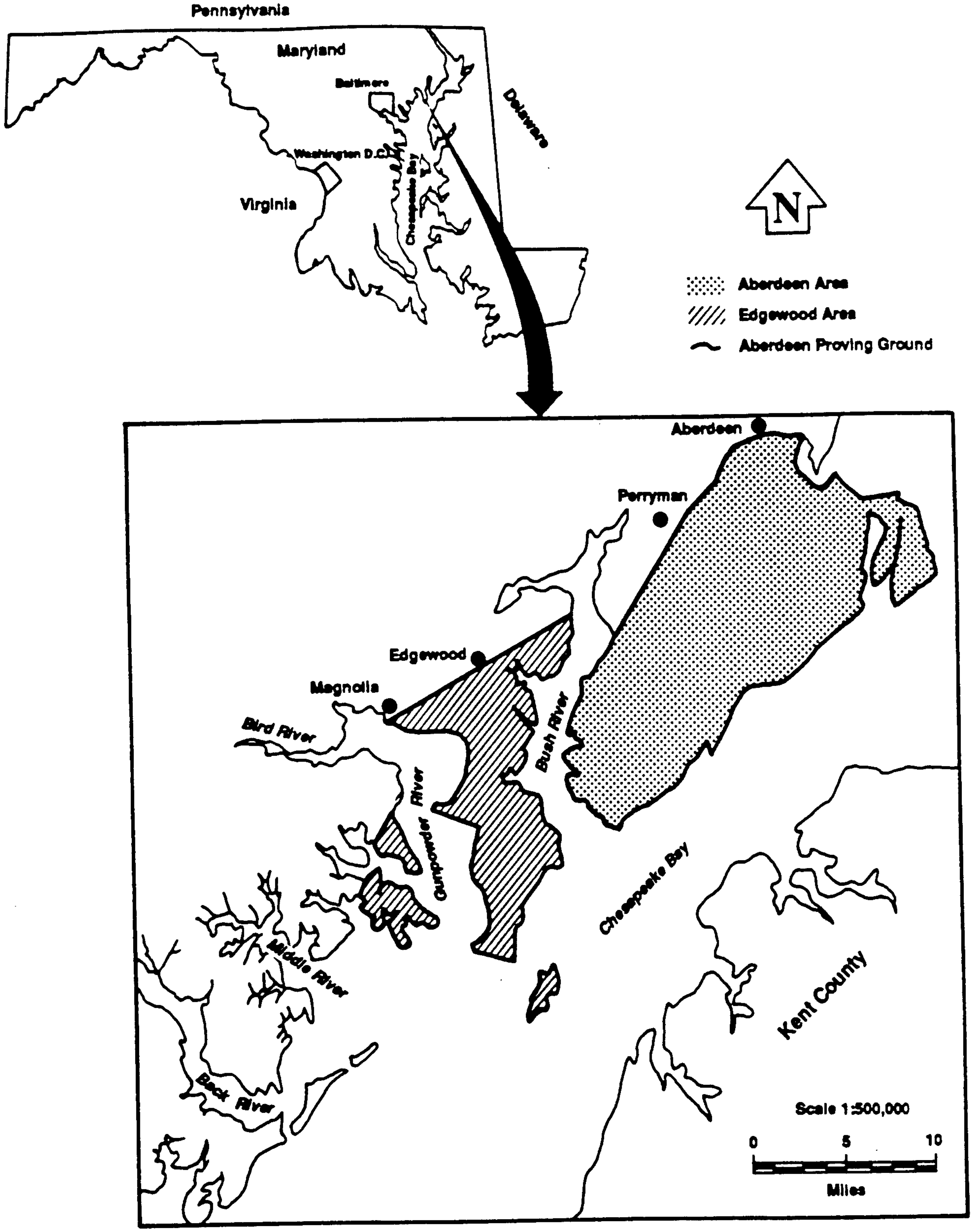
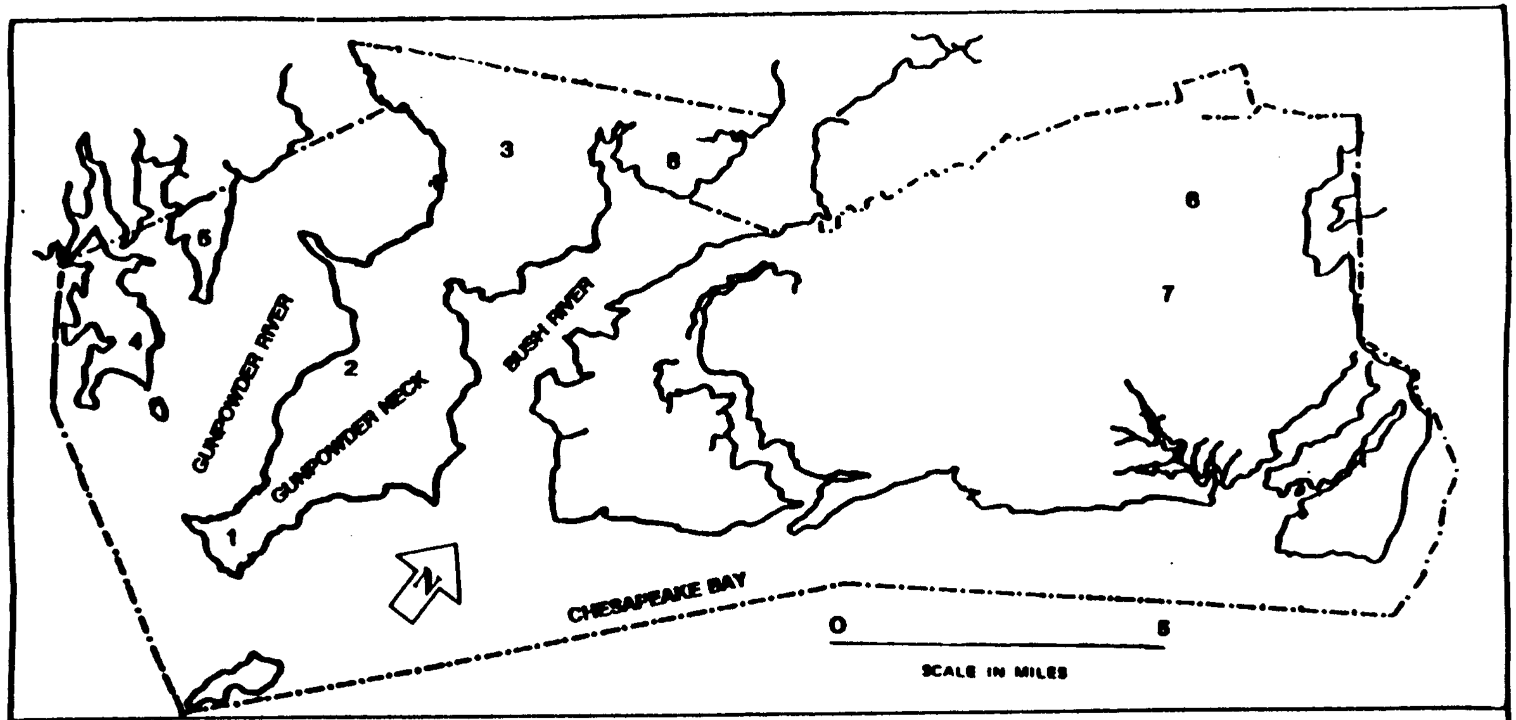


Figure 2-2

Aberdeen Proving Ground Study Area Locations



1. J FIELD
2. O FIELD
3. CANAL CREEK
4. CARROLL ISLAND
5. GRACES QUARTERS
6. PHILLIPS ARMY AIRFIELD STUDY AREA
7. MICHAELSVILLE LANDFILL
8. NIKE

(AEHA), the U.S. Army Ballistics Research Laboratory (USABRL), and the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA).

Aside from industrial and residential areas in the Canal Creek Area of Edgewood and the northeastern portion of the Aberdeen peninsula, much of the land at APG is relatively undeveloped. These areas are used predominantly as testing ranges. Portions of APG also are used recreationally by active and retired APG personnel and their families and guests. Recreational activities include hunting, trapping, and shoreline fishing and crabbing from designated areas. Commercial and recreational fishing from boats also is permitted (for APG personnel and the public) in all navigable waters unless an area is restricted due to testing[1]. None of the inland water bodies at APG are suitable or likely to be used for swimming either due to their size or inaccessibility (highly vegetated/steep banks). Swimming in off-shore waters is possible although officially prohibited by APG and enforced by patrol boats.

2.4 ECOLOGY

APG contains extensive woodlands, wetlands, and shoreline bordering the Chesapeake Bay and Bush and Gunpowder Rivers. Based on data from 1985, the cover types at APG are characterized approximately as follows: 50% forest, 34% mowed areas, 13% marsh or marsh shrub, 2% bare earth, and 1% shrub (APG 1987). All forests on the Proving Ground are hardwood forests and represent a transition area between the oak-pine and oak-chestnut forest regions. The forested areas are dominated by trees varying from saplings to heavy timber. Mowed areas are dominated by a variety of grasses and forbs, including goldenrod, aster, daisy, milkweed, and ragweed. Much of the marsh vegetation consist primarily of herbaceous plants including grasses, sedges, cattails, *Phragmites*, arrowhead, and pickerelweed, although some forested wetlands occur at APG. Marsh shrub is dominated by shrubs such as salt beech (*Baccharis halimifolia*) and shrub areas are dominated by a variety of woody shrubs.

Many different terrestrial animals are found on APG, including 39 reptile and amphibian species, over 40 mammalian species, and 121 species of birds. A complete list of the wildlife species documented at APG is presented in Appendix D.

White tailed deer (*Odocoileus virginianus*) and beaver (*Castor canadensis*) are two of the most abundant large mammals at APG. Cottontail rabbits (*Sylvilagus floridanus*) also are prevalent. Muskrats (*Oridatra zibethica*), raccoons (*Procyon lotor*), red and grey foxes (*Vulpes fulva* and *Urocyon cinereoargenteus*), woodchucks (*Marmota monax*), skunk (*Mephitis mephitis*), chipmunks (*Tamias striatus*), gray squirrels (*Sciurus carolinensis*), and otters (*Lutra canadensis*) are found in higher concentrations at APG than in surrounding areas.

Wild turkeys (*Meleagris gallopavo*) have been introduced to APG from game stocks in the last few years and are now established. Other bird species present at APG include the endangered peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliacetus leucocephalus*).

The aquatic ecosystems of APG and the nearby aquatic systems of the Upper Chesapeake Bay represent extremely sensitive ecological areas. Submerged aquatic vegetation along several areas of the APG shoreline provides shelter for all ages of fish and invertebrates, as well as an important food source for waterfowl. The upper portions of Chesapeake Bay, including many major tributaries such as the Gunpowder and Bush Rivers, are critical spawning and nursery habitats for a number of

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[1] The following waterways are considered navigable: Gunpowder River, Bush River, Chesapeake Bay, Dundee Creek, Saltpeter Creek, and Hawthorn Cove.

recreationally and commercially important fish such as striped bass (*Morone saxatilis*), white perch (*Morone americana*), American shad (*Alosa sapidissima*), alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*). The blue crab (*Callinectes sapidus*) is also found in the waters in the southern portions of APG. The freshwater habitat close to (but upstream of) APG is the only known habitat of the endangered Maryland darter (*Etheostoma sellare*). A complete list of fish species found at APG and in the surrounding waters of the upper Chesapeake Bay is provided in Appendix D.

The extensive freshwater wetlands at APG represent some of the last relatively undisturbed examples of such ecosystems. These wetlands are important as wintering and breeding grounds for waterfowl and as habitat for muskrat, otter, and mink (*Mustela vison*) as well as many other species. Marshes are also sources of food for birds, turtles, and estuarine organisms (at high tide) in that they contain vegetation and are breeding grounds for invertebrates.

Specific information about the habitat of each study area is given in the baseline risk assessments for each study area.

2.5 GEOLOGY

APG is located in the Atlantic Coastal Plain physiographic province, immediately southeast of the fall line separating the coastal plain from crystalline rock of the Piedmont province. The surficial geology at APG is comprised of unconsolidated fluvial sediments consisting of beds of clay, silt, sand, and occasional gravel lenses. These unconsolidated sediments range in thickness from about 150 feet in northern and western areas of APG (near the fall line) to more than 600 feet in southeastern portions of the installation. Crystalline bedrock of Precambrian to lower Paleozoic age underlies the coastal plain sediments and consists chiefly of schist, gneiss, gabbro, granite, marble, and quartzite.

The geologic formations within APG (from oldest to youngest) are the Potomac group, Talbot formation, and the recent alluvium. The Potomac group is of the Cretaceous age and its three divisions, Patuxent, Arundel, and Patapsco, line the drainage ways of APG and are often mapped together due to their lithographic similarities. This group consists of interbedded gravel, sand, silts and clays. It is generally gravelly at the base, clayey in the middle, and sandy to clayey at the top; although the thickness and lateral extent of zones are widely variable. Coarser material such as sandy gravel occurs as discrete channel fills. The Talbot formation of the Pleistocene series and the alluvium of Recent age occur throughout most of APG. The Talbot formation covers higher ground whereas the newer alluvial deposits occur at lower elevations along the streams and shorelines. These surficial sediments are heterogeneous, containing materials ranging from clay to boulders and varying considerably with lateral direction. Typically, however, the formation is more gravelly at the bottom with sand and clay found more towards the top.

Soils of APG vary in thickness and type, with three soil series found within the installation. The Elkton and Keyport series have high runoff rates and are relatively impermeable clay soils found in low areas. The third series, Sassafras, is more permeable and more extensive.

2.6 GROUNDWATER AND SURFACE WATER HYDROLOGY

Surface drainage at APG is to the Chesapeake Bay or Bush and Gunpowder River estuaries, or to their tributary creeks. With the exception of the Nike site, all of the study areas in the Edgewood Area drain into the Gunpowder River. The longest drainage-way is the East Branch of Canal Creek, which eventually meets the West Branch of Canal Creek in a marshy area and flows into the Gunpowder River. O-Field is drained by Watson Creek, which also flows into the Gunpowder River, whereas

J-Field drains through wetlands and drainageways into Gunpowder River and the Bay. Graces Quarters and Carroll Island drain directly or by way of tributaries into Gunpowder River and the Chesapeake Bay. The Nike site drains to Lauderick and Monks Creeks, which are tidal tributaries of the Bush River. Of the Aberdeen Area study areas, both Michaelsville Landfill and Phillips Army Airfield drain to Chesapeake Bay via Romney Creek.

The lower reaches of the Bush and Gunpowder Rivers, as well as many creeks and wetlands within the boundaries of APG are tidally influenced, with tidal ranges varying from about 0.5 to 1.5 feet depending on the specific location. Tidally influenced water bodies include Canal, Watson, Kings, Lauderick, and Monks Creek in the Edgewood Area, and Romney Creek in the Aberdeen Area.

The groundwater table across APG is encountered within 6 m of the surface, and generally reflects the topography and proximity to surface water bodies. Groundwater at APG exists in a series of permeable zones of sand and gravel, which are for the most part isolated by silt and clay confining layers. The setup of these layers varies considerably, and a set of formations can be part of the same or different aquifers in different areas. The principal groundwater-bearing formation at APG is the Patuxent formation. The Patapsco formation also has beds of sand and gravel that yield water. The Arundel clay separates the Patapsco and Patuxent formations in the vertical sequence of coastal plain deposits, and generally act as a confining unit at APG, exhibiting very low water yields.

Groundwater is recharged by vertical downward infiltration of precipitation and is discharged via several mechanisms. Groundwater can discharge by movement into wells (sometimes by upward leakage), by downward leakage to lower aquifers, by lateral movement to surface water, or by evapotranspiration. In areas located in close proximity to tidal creeks and wetlands, groundwater in upper aquifers is sometimes tidally influenced, and exhibit periodic variations in hydraulic gradient and flow rate. Some tidally influenced aquifers at APG may be subject to periodic reversals in groundwater flow direction as a result of tidal effects, resulting in complex discharge-recharge relationships with surface water bodies.

2.7 DOMESTIC AND INDUSTRIAL WATER SOURCES

Surface water has been the primary source for potable and nonpotable water for the installation since it was established. All current sources of potable surface water are off-post and upgradient of APG, although water from the Bush River and East Branch of Canal Creek were used during World War I. Drinking water for the Edgewood Area is obtained from Winters Run and that for Aberdeen area from Deer Creek.

Groundwater is the secondary source of water for APG. Historically, when surface water supplies have not been sufficient to meet water needs, water from groundwater wells has been used for both potable and nonpotable water. Groundwater usage in the Edgewood area was first mentioned in a history of World War I activities (AEHA 1989). The water from numerous wells was used for sanitary and drinking water and for boiler feed water. The exact number of wells used during WWI is not known, but it is possible that there were a dozen or more. During 1941 and 1942, 14 wells were installed. Eight of these wells were not used extensively, but the remaining six were considered part of the Edgewood area water supply system until they were found to be contaminated in 1984. At least 100 wells have been drilled on the Aberdeen area since 1917. Many of these wells are out of service or abandoned, although the number of these is unknown.

There is no current use of the groundwater in the Edgewood area except for two wells in H-Field that were once used to a limited extent for potable water in the past but are presently used only for vehicle washing. A well was installed on Carroll Island in 1961; it was used for nonpotable water and for a portion of the potable water. In addition, a hand-dug well still exists on Carroll Island and was once used to a limited extent to obtain nonpotable water. Neither of these wells are currently in use. A water supply well installed in 1954 exists in C-field (north of O-Field), but this well is not used currently and has not been used in the recent past. There also is a hand-dug well still in existence at Graces Quarters. The historical use of this well is unknown.

The City of Aberdeen and Harford County are the largest groundwater users in the area. The City of Aberdeen has three water supply wells in the Aberdeen area, which are set in Talbot sediments at shallow depths. Harford County has four wells located along the Aberdeen area boundary east and northeast of the town of Perryman. These city and county wells are upgradient of the study areas being evaluated in the risk assessment. The Aberdeen area has three standby wells in the northeast portion of the Aberdeen area set in the deeper sediments divided from the shallow zone by a thick clay layer.

2.8 METEOROLOGY

Because of APG's proximity to the Chesapeake Bay and Atlantic Ocean, its climate is more moderate than inland areas, with milder winters and higher humidity. Weston (1978 in ESE 1981) summarized the following climatological data for the years 1949-1964. These data show percent relative humidity ranges from the mid 60s to the low 70s all year. Precipitation is somewhat constant, with a maximum in August of 5.04 inches and a minimum in October of 2.3 inches. Average annual precipitation ranges from 39.3 inches to 45 inches. In the winter mean daily temperature is 33.8°F but in the summer it can go up to 75.2°F. Predominant wind direction is NW to NNW in the winter and S to SSW in the summer. Average wind speed ranges from 6.03 mi/h in the summer to mid fall and up to 7.02-9 mi/h the rest of the year.

2.9 REFERENCES

The following sources were cited in this chapter:

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3.0 DATA SOURCES AND QUALITY ASSURANCE

As noted in Chapter 1, the baseline risk assessments presented in this report are based entirely on existing data gathered during site investigations and environmental monitoring studies performed at APG by the U.S. Army and its contractors. Initial steps for Clement and ICF KE in the risk assessment process involved gathering these data from all available sources; evaluating data quality with regard to sampling and analytical factors; and compiling this information into an appropriate format for performing the statistical analyses necessary for the risk assessment. This chapter presents an overview of the data sources used to perform the risk assessments, and discusses quality assurance aspects of these data, which serve as the basis for the information presented in this report.

The chapter is organized in four sections: (1) an overview of the principal data sources for the risk assessments (i.e., the government agencies that have been involved in major data-gathering efforts at APG); (2) a summary of previous investigations performed at the eight study areas; (3) a discussion of quality assurance (QA) issues related to available chemical data; and (4) a summary describing QA and data management issues for the baseline risk assessments.

3.1 DATA SOURCES

Chemical concentration data for the baseline risk assessments were gathered from four principal sources:

- USATHAMA Installation Restoration Data Management System (IRDMS): The IRDMS contains more than 40,000 chemical data records on APG, including information from investigations conducted from 1975 to the present by USATHAMA, other government agencies (e.g., USGS), and private contractors. Data are classified by environmental medium (e.g., groundwater, soil, surface water, sediment) and location, and are linked to hydrogeologic, geologic, and survey data files. Data generated according to USATHAMA-certified analytical methods have been subjected to an automated IRDMS data validation routine; however, much non-validated and potentially poor-quality information is also contained in the APG IRDMS file.

- U.S. Geological Survey (USGS): The USGS Water Resources Division office in Towson, Maryland, conducted hydrogeologic assessments and groundwater contamination studies at several sites at APG during the period 1985 to 1991. Areas that have been or are currently under investigation by USGS include Old O-Field, New O-Field, J-Field, Canal Creek, Carroll Island, and Grace's Quarters. Although some multimedia sampling has been performed by USGS, the investigations have generally focused on hydrogeologic characterization and groundwater quality assessment. These studies are described in greater detail in Section 3.2.

- U.S. Army Corps of Engineers Waterways Experiment Station (USAEWES): USAEWES (located in Vicksburg, Mississippi) was the lead agency for several investigations at the Aberdeen Area, including the Michaelsville Landfill remedial investigation (RI) and the Aberdeen Area RCRA facility assessment (RFA).

- U.S. Army Environmental Hygiene Agency (AEHA): AEHA performed extensive investigations and environmental monitoring studies at APG over the period 1972-1990. AEHA has prepared the Edgewood Area RFA, a comprehensive document containing detailed information on more than 700 potential contamination sources at Edgewood (including all of the six APG-EA areas being evaluated in this risk assessment). In addition, AEHA has conducted hydrogeologic assessments at the Nike site and Phillips Army Airfield landfill, and has performed numerous surface water, sediment, and biological studies at APG, including monitoring activities in Canal, Kings, and Watson Creeks.

Section 3.2 provides a discussion of the individual studies and investigations that provided data for the eight priority areas included in the baseline risk assessment.

3.2 SUMMARY OF PREVIOUS INVESTIGATIONS

This section presents an overview of previous investigations performed at the eight sites being evaluated in the baseline risk assessment. It should be noted that this section is not intended to be a comprehensive summary of every previous study performed at APG, nor does it provide a detailed discussion of the major findings from these investigations. Rather, this summary focuses on investigations or monitoring studies considered to be of most importance to the risk assessments, and provides an overview of the types and quantities of information available for each site. The quality of this information related to sampling and analytical methods and other QA factors is then discussed in the following section.

3.2.1 O-FIELD

The major source of chemical data for the Old O-Field area and nearby Watson Creek is the USGS Hydrogeologic Assessment (HGA) conducted from 1985 to 1989. This study focused on evaluating local hydrogeology and groundwater quality, but also included collection of some surface water and sediment samples from Watson Creek (the suspected discharge point for a contaminated groundwater plume migrating from the Old O-Field source area) and the Gunpowder River, as well as very limited subsurface soil sampling. The USGS studies at Old O-Field (as well as other studies described in this subsection) are summarized in Table 3-1.

In addition to the USGS study, several monitoring projects were conducted in the Old O-Field area by AEHA, including (1) sediment sampling and a macroinvertebrate species diversity study in Watson Creek in 1987; (2) a 1985 study involving surface water and sediment sampling, fish tissue residue analyses, and a macroinvertebrate community diversity assessment; and (3) surface water, sediment, fish, and clam tissue sampling performed in 1978. USATHAMA also performed an investigation of groundwater and surface water contamination at O-Field from the period 1977 to 1983; this study involved installation of the first groundwater monitoring wells at Old O-Field and provided initial evidence that groundwater, surface water, and sediment in the vicinity of the site were contaminated. Both the USATHAMA investigation and the 1985 and 1987 AEHA studies (Biological Survey of Canal, Kings, and Watson Creeks and APG Sediment Analyses, respectively) encompassed several study areas in the Edgewood Area in addition to O-Field.

Investigations directed at characterizing chemical contamination at New O-Field have been very limited; USGS studies that will eventually provide more information on this site are currently in the planning stage.

TABLE 3-1

SUMMARY OF SITE INVESTIGATIONS

O-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses: Analytes	Analyses: Comments	Summary of Key Findings (a)
USGS (1988, 1989a)	Groundwater	1985-1986 (~ quarterly), 9/87 (selected wells)	Volatile organics	TICs identified (b)	Groundwater contains high levels of volatile organic chemicals, thiodyglycol, 1,4-dithiane, and various metals, including As and Zn.
			Base neutral organics	TICs identified (b)	
			Metals/inorganics	Including all priority pollutant metals/inorganics, except Ag (c); Be, Pb, Hg, Se, Cu, Cr, Ni analyzed in only one sampling round	
			Water quality parameters (d)	--	
		12/86, 9/87 (selected wells)	Explosives/related compounds	TNT, 2,4-DNT, 2,6-DNT, HMX, RDX, 1,2,3-TNB, 1,3-DNB, tetryl and nitrobenzene	
		9/87 (selected wells)	Agents/related compounds	Mustard, GB, GD, VX and selected breakdown products	
		1 event (date unspecified) (selected wells)	Radionuclides	Gross beta, gross alpha, tritium, and cesium 137	
		1 event (date unspecified) (selected wells)	Herbicides	2,4-D, silvex, and 2,4,5-T	
	Soil (subsurface)	1 event (date unspecified) (selected locations)	Metals	Sb, As, Fe, Mn only	As levels generally are low in subsurface soils, although higher concentrations closer to source areas were evident in some samples.
	Surface water	8/85 (all locations), 1984, 1987 (selected locations)	Volatile organics	TICs identified (b)	Surface water contains elevated levels of several heavy metals including As, Zn, Hg, and Se.
			Base neutral organics	TICs identified (b)	
			Metals/inorganics	Including all priority pollutant metals/inorganics except Ag, CN, and Tl (c)	
			Water quality parameters (d)		
	Sediment	8/85 (all locations), 1984, 1987 (selected locations)	Volatile organics	TIC identified (b)	Sediment contains elevated levels of several heavy metals including As, Zn, Hg, and Se.
			Base neutral organics	TICs identified (b)	
			Metals/inorganics	Including all priority pollutant metals/inorganics except Ag (c)	

See footnotes at the end of table.

TABLE 3-1 (Continued)

SUMMARY OF SITE INVESTIGATIONS

O-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses: Analytes	Analyses: Comments	Summary of Key Findings (a)
AEHA (1987) (e)	Sediment	7/86	Metals/inorganics	Including all priority pollutant metals (c)	As levels in Watson Creek sediment are elevated, relative to other sample locations in the Edgewood and Aberdeen areas. Pb and Zn concentrations in sediments also may be elevated.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Aroclors 1242, 1248, 1254, 1260	
	Macroinvertebrates	7/86	Species diversity	--	Macroinvertebrate study results were inconclusive.
AEHA (1985) (e)	Surface water	1984-1985 (4 events)	Volatile organics	--	Watson Creek contains detectable, but low levels of volatile and semivolatile organic chemicals. Cu, Pb and Zn concentrations in Watson Creek are above aquatic life criteria.
			Base neutral organics	--	
			Metals	Priority pollutant metals (c)	
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Seven Aroclors analyzed	
			Water quality parameters (d)	--	
	Sediment	1984-1985 (2 events)	Metals	Priority pollutant metals (c)	Watson Creek sediments may contain elevated levels of some metals. Pesticide and PCBs were undetected or were present at low levels.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Aroclors 1242, 1248, 1254, 1260	
	Fish (muscle)	5/85	Metals	Priority pollutant metals (c)	Metal and pesticide concentrations in fish tissue were below concentration levels of concern for human consumption.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
	Macroinvertebrates	9/84	Species diversity	--	Macroinvertebrate species diversity suggested poor water quality.

See footnotes on the following page.

TABLE 3-1 (Continued)

SUMMARY OF SITE INVESTIGATIONS

O-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USATHAMA (1983) (e,f)	Groundwater	1977 (single event; some wells sampled twice)	Volatile organics Base neutral organics Metals/inorganic APG-specific chemicals	-- -- -- Including white phosphorous, thiodiglycol	Groundwater adjacent to and downgradient of O-Field is highly contaminated with volatile organic chemicals and chemical agent degradation products, including As.
	Surface water	1976-1979 (Sampling events unspecified)	Volatile organics Base neutral organics Metals/inorganics APG-specific chemicals	-- -- -- Including white phosphorous, thiodiglycol	Low-levels of volatile organic chemicals and As are discharging to Watson Creek.
	Sediment	1976-1979 (Sampling events unspecified)	Volatile organics Base neutral organics Metals/inorganics APG-specific chemicals	-- -- -- Including white phosphorous, thiodiglycol	As appears to be elevated in Watson Creek sediments. Bis(2,4,6-trichlorophenyl)urea found in 27 of 33 locations in the Gunpowder River and its tidal creeks. Dichlorobenzene and trichlorobenzene were found in Watson Creek near Old O-Field.
AEHA (1978) (e)	Surface water	7/77	Metals/inorganics Water quality parameters (d)	Including As, Cd, Cu, Pb, As, Zn, Ni, Hg --	Plant nutrients were excessive in Watson Creek surface water. Ag and Cu may be present at concentrations toxic to aquatic life.
	Sediment	7/77	Metals/inorganics Pesticides PCBs	Including As, Cd, Cu, Pb, As, Zn, Ni, Hg Including chlorinated pesticides, organophosphates, and selected herbicides Aroclors 1242, 1248, 1254, 1260	Plant nutrients were excessive in Watson Creek sediment. Cu, Cd, and Zn appear to be elevated in sediments of Watson Creek.
	Fish and clams (tissue unspecified)	7/77	Metals	As, Cd, Cu, Pb, Zn, Ni, Hg only	Levels of Zn, Pb, and Cu in fish/clam tissue appear to be elevated relative to that observed in other Atlantic coast waters.

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) Tentatively identified compounds (TICs) are chemicals identified during a library search of mass spectra.
(c) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(d) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.
(e) This study encompassed several study areas at Aberdeen Proving Ground. Only information related to O-Field is summarized here.

3.2.2 J-FIELD

A summary of previous investigations at J-Field is presented in Table 3-2. As indicated, J-Field has been the focus of investigations by USGS (1988-present), AEHA (1986-1989), Princeton Aqua Science (1984), and USATHAMA (1976-1983). The majority of these efforts have involved mostly groundwater sampling, with limited soil and surface water sampling performed by USGS, AEHA, and Princeton Aqua Science. USATHAMA sediment sampling from 1976-1979 represents the only information regarding this medium that has been collected during environmental investigations at the site.

3.2.3 CANAL CREEK

USGS performed a large-scale hydrogeologic and groundwater contamination study in the Canal Creek watershed (as well as a small portion of the Kings Creek drainage) from 1986 to 1989, including the installation of 87 monitoring wells and collection of several hundred groundwater samples. In addition , USGS collected soil and surface water samples at 45 and 18 locations, respectively, in the Canal Creek area (see Table 3-3). The USGS investigations represent the principal source for data used in the baseline risk assessments. Other data sources for the Canal Creek area include the 1985 and 1987 AEHA studies described previously for O-Field; as noted, these studies included sediment, surface water, and fish tissue analyses, as well as macoinvertebrate community diversity studies.

Environmental investigations in Canal Creek commenced with a 1957 water quality study, which was followed up by an investigation in 1962. USATHAMA included Canal Creek in its installation-wide investigation of APG-EA (1977-1983), and collected surface water, sediment, soil, and groundwater samples for chemical analysis. An additional study of potential importance to the baseline risk assessment was performed in 1980-1981 when the U.S. Army Medical Bioengineering Research and Development Laboratory conducted an evaluation of the presence of bis(2,4,6-trichlorophenyl)urea (TCPU) in Canal Creek (TCPU is the major component of the protective-clothing impregnating agent CC2, which was manufactured extensively in the Canal Creek area from the 1940s to 1970s).

3.2.4 CARROLL ISLAND

A summary of previous investigations performed at Carroll Island is presented in Table 3-4. As shown, USGS conducted the most recent and comprehensive studies at this site, including groundwater, soil/sediment, and surface water sampling performed from 1988 to 1990. As has been noted for other study areas, the USGS investigation focused mainly on groundwater contamination and hydrogeologic assessment, with limited sampling of other environmental media.

USATHAMA performed groundwater, surface water, sediment, and soil sampling at Carroll Island as part of their APG-EA study (1977-1983); in addition ,several biological studies were performed during the early to late 1970s by the Chemical Research, Development, and Engineering Command (CRDEC) to determine whether open-air testing of lethal chemical agents on the island had resulted in adverse effects to wildlife (e.g., Slack et al. 1972, Pinkham et al. 1976, Ward, 1979). These studies focused on species distribution, diversity, and abundance in specific components of the Carroll Island ecosystem (e.g.,reptiles, zooplankton).

TABLE 3-2

SUMMARY OF SITE INVESTIGATIONS

J-FIELD

			Analyses		
Agency/Organization	Media Sampled	Sampling Period or Event	Analytes	Comments	Summary of Key Findings (a)
USGS (1990a)	Groundwater	5/90 - 6/90 and Spring 1991	Volatile organics	--	No results have been published yet.
			Base neutral organics	--	
			Metals/inorganics	Including priority pollutant metals/ inorganics (b)	
			Water quality parameters (c)	--	
			Pesticides	Including organochlorine pesticides, organophosphates	
			PCBs	Aroclors 1016, 1221, 1242, 1248, 1254, 1260	
			Explosive compounds	Including 2,4-DNT, 2,6-DNT, 1,3-DNB, nitrobenzene, nitroglycerin, PETN, HMX, RDX, tetryl, tetrazene, nitrocellulose, isophorone, 2,4,6-trinitobenzaldehyde, 2,4,6-TNT, 1,3,5-TNB	
			Organosulfur compounds	Including oxathiane, 1,4-dithiane, p-chlorophenylmethylsulfone, p-chlorophenylmethylsulfide, p-chlorophenylmethylsulfoxide, benzothiazole, thiodigylcol	
			Mineralogy	--	
	Surface Water	9/88	Volatile organics	--	No results have been published yet.
			Water quality parameters (c)	--	
			Metals	Including priority pollutant metals (b)	

See footnotes at the end of table.

TABLE 3-2 (Continued)

SUMMARY OF SITE INVESTIGATIONS

J-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
AEHA (RFA sampling) (1989a) (d)	Groundwater	9/86	Volatile organics	--	Elevated levels of dissolved solids were found in one area. Low but detectable levels of metals, dissolved Cd, Pb, Se were seen. High detection of VOCs with 0.560 mg/L trichloroethene seen at the downgradient end of the burning pits.
			Base neutral organics	--	
			Metals/Inorganics	Including priority pollutant metals/inorganics (b) except Sb, Be, Cu, Ni, Tl, Zn	
			Pesticides	--	
			PCBs	--	
			APG specific chemicals	Including thiodiglycol	
			Explosive related compounds	Including 2,4,6-TNT, 2,4-DNT, 2,6-DNT, RDX, HMX, tetryl	
			Radiochemistry	Including gross alpha and beta, potassium 40, strontium 90, radium-226 and -228	
	Soil	8/86 - 9/86	Volatile organics	--	Elevated levels of Ag, Be, Cd, Cr and Pb found in J-Field soil. Various samples also contained high TEP levels of Cd, and/or Pb. The pesticide compounds heptachlor epoxide, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were detected. Detectable levels of PCB 1248, PAHs, naphthalene compounds, chlorinated benzene, and hydrocarbons were also found.
			Base neutral organics	--	
			Metals	Including priority pollutant metals (b) except Sb, Be, Cu, Ni, Tl, Zn	
			Pesticides	--	
			PCBs	--	
			Explosive related compounds	Including 2,4,6-TNT, 2,4-DNT, 2,6-DNT, RDX HMX, tetryl	
		2/88	Radionuclides	Beta and gamma emitters	No detection of radation higher than background levels.

See footnotes at the end of table.

TABLE 3-2 (Continued)

SUMMARY OF SITE INVESTIGATIONS

J-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses Analytes	 Comments	Summary of Key Findings (a)
AEHA (RFA sampling) (1989a) (d) (Cont.)	Standing Water	8/86 - 9/86	Volatile organics	--	Low levels of Cd, Hg, and Pb were found in J-Field standing water.
			Base neutral organics	--	
			Metals	Including priority pollutant metals (b) except Sb, Be, Cu, Ni, Tl, Zn	
			Pesticides	--	
			PCBs	--	
			Explosive related compounds	Including 2,4,6-TNT, 2,4-DNT, 2,6-DNT, RDX HMX, tetryl	
			Radiochemistry	Including gross alpha and beta, strontium-90, radium-226 and -228.	
Princeton Aqua Science (1984) (d)	Groundwater	1983 (9 wells)	Water quality parameters	pH, specific conductance, TOC, TOX only	The most significant finding was high TOX levels found in two wells east and north of the toxic burning pits.
			Petroleum hydrocarbons	--	
			Metals/Inorganics	--	
			Volatile organics	--	
			Pesticides	--	
			PCBs	--	
	Soil	1983 (11 sites)	Soil quality parameters	pH, specific conductance only	Soil in toxic burning pits contained petroleum hydrocarbons and elevated levels of various metals, most notably lead.
			Petroleum hydrocarbons	--	
			Metals/Inorganics	Including CN	
			Volatile organics	--	
			Base neutral organics	--	
			Pesticides	--	
			PCBs	--	

See footnotes on the following page.

TABLE 3-2 (Continued)

SUMMARY OF SITE INVESTIGATIONS

J-FIELD

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USATHAMA (1983) (d,e)	Groundwater	2/77, 3/77, 8/77, or 9/77 (9 wells)	Metals/inorganics	Hg, Cu, Zn, Fe, Ag, S, NO3, As, Kjeldahl nitrogen and total phosphate only	Because of limited monitoring of organics the study was not able to adequately define groundwater contamination by organic priority pollutants. However, several volatile and semi-volatile organic compounds were detected in groundwater. Tetrahydrofuran and methylethyl ketone were detected at the highest concentrations.
			Water quality parameters	TOC, COD, chlorine demand and TDS only	
			APG-specific chemicals	Including white phosphorus, thiodiglycol, and cholinesterase inhibitors only	
		2/77, 3/77, 8/77, or 9/77 (8 wells)	Base neutral organics	--	
		9/77 (4 wells)	Volatile organics	--	
	Surface Water	1976 - 1979 (17 samples)	Volatile organics	--	Concentrations of migrating contaminants were too small to have an effect on Gunpowder River or Chesapeake Bay.
			Base neutral organics	--	
			Metals/inorganics	Including As	
			APG-specific chemicals	Including white phosphorus, thiodiglycol	
	Sediments	1976 - 1979 (Sampling events unspecified)	Volatile organics	--	TCPU was found in the sediments in 27 of 33 stations in Gunpowder River. No WP was found.
			Base neutral organics	--	
			Metals/inorganics	Including As	
			APG-specific chemicals	Including white phosphorus, thiodiglycol	

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.
(d) Information for this study is summarized from discussions in AEHA (1989a).
(e) This study encompassed several study areas at Aberdeen Proving Ground. Only information related to J-Field is summarized here.

TABLE 3-3

SUMMARY OF SITE INVESTIGATIONS

CANAL CREEK

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USGS (1989b) (Compilation of several USGS studies)	Groundwater	1986-1987 (87 wells)	Volatile organics	TICs identified in 1989 and for some samples in 1988	In Phase I sixteen volatile organic chemicals were detected in the two shallow aquifers, while the organic chemicals that were detected in the lower confining aquifer were considered to be laboratory contaminants. No results have been published for Phases II, III, or IV.
		1988	Base neutral organics	TICs identified in 1989 and for some samples in 1988	
		5/89			
		9/89	Metals/inorganics	Includes all priority pollutant metals (b), TICs identified	
			Water quality parameters (c)	Temperature, pH, TDS	
	Soil (surface)	1989 (45 locations)	Volatile organics	TICs identifed	No results have been published yet.
			Semivolatile organics	TICs identified	
			Metals/inorganics	Including priority pollutant metals except Be, Ni, Ag, and Tl	
			Pesticides	Including chlorinated pesticides	
			PCBs	Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	
	Surface Water	1988 (18 locations)	Volatile organics	TICs identified in a portion of the samples	No results have been published yet.
		6/89	Semi-volatile organics	TICs identified in a portion of the samples	
			Metals/inorganics	Including priority pollutant metals/inorganics (b) except Se.	
			Pesticides	Including chlorinated pesticides, organophosphates	
		12/89	Volatile organics	--	

See footnotes at the end of table.

TABLE 3-3 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CANAL CREEK

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
AEHA (1987) (d)	Sediment	7/86	Metals	Priority pollutant metals (b)	Sediment, in one of the samples collected in the Canal Creek area, had the highest concentrations of chromium and lead detected across 35 study locations in the Edgewood and Aberdeen areas. Cu, and Hg concentrations also were elevated.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Aroclors 1242, 1248, 1254, 1260	
	Macroinvertebrates	7/86	Species diversity	--	Macroinvertebrate study results were inconclusive.
AEHA (1985) (d)	Surface Water	1984-1985 (4 events)	Volatile organics	--	Canal Creek surface water contains detectable but low levels of volatile and base neutral chemicals. Be, Cu, Pb, and Zn in surface water exceed aquatic life criteria.
			Base neutral organics	--	
			Metals	Priority pollutant metals (b)	
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Seven Aroclors analyzed	
			Water quality parameters (c)	--	
	Sediment	1984-1985 (4 events)	Metals	Priority pollutant metals (b)	Metal concentrations in sediment appear to be elevated relative to Watson Creek and Kings Creek. Canal Creek sediments contain high concentrations of PCBs.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Aroclors 1242, 1248, 1254, 1260	
	Fish (muscle)	5/85	Metals	Priority pollutant metals (b)	These compounds were detected but were at concentrations below criteria levels for human consumption.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	

See footnotes at the end of table.

TABLE 3-3 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CANAL CREEK

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses Analytes	 Comments	Summary of Key Findings (a)
AENA (Cont.) (1985) (d)	Macroinvertebrates	9/84	Species diversity	--	Macroinvertebrate species diversity suggested poor water quality.
AMBRDL (1983) (e)	Sediments	1980-81	TCPU	--	TCPU is present in sediments of Canal Creek. The trichloroaniline found in USATHAMA (1983) was all or mostly due to thermal degradation of TCPU on the GC column.
USATHAMA (d,e) (Sampling by CRDEC) (Unpublished)	Groundwater	1979-1983	Ongoing monitoring of wells from USATHAMA Contamination Survey (1983)	--	No problems identified which have not already been published.
USATHAMA (1983) (d,e)	Groundwater	Event(s) unspecified	Metals	As only	No contamination problems identified. However, there were many problems with the study in that the wells were poorly situated, VOCs were not recognized as contaminants of concern, and existing supply wells and deeper groundwater were not sampled.
			APG-specific chemicals	Including white phosphorus and thiodiglycol	
		1/77, 3/77, or 5/77 (Selected locations)	Volatile organic compounds	--	
			Base neutral organics	--	
			Metals/inorganics	--	
	Surface Water	1976-1979 (Sampling events unspecified)	Volatile organic compounds	--	Low levels of WP were found in the surface water of Canal Creek.
			Base neutral organics	--	
			Metals/inorganics	--	
			APG-specific chemicals	Including white phosphorus and thiodiglycol	

See footnotes on the following page.

TABLE 3-3 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CANAL CREEK

			Analyses		
Agency/Organization	Media Sampled	Sampling Period or Event	Analytes	Comments	Summary of Key Findings (a)
USATHAMA (cont.) (1983) (d,e)	Sediment	Sampling dates unspecified	Volatile organic compounds	--	Low levels of WP were found in the sediment of Canal Creek. Trace levels of saturated aliphatic hydrocarbons, alcohols, aldehydes, ketones, esters, and carboxylic acids also were found. However, the study concluded that these chemicals were unlikely to be present due to activities at APG. Bis-(2,4,6-trichlorophenyl)urea was found in sediments in 27 of 33 sampling stations all along the Gunpowder River. Trichloroaniline was also detected in the sediments.
			Base neutral organics	--	
			Metals/Inorganics	--	
			APG-specific chemicals	Including white phosphorus and thiodiglycol	
AEHA (1978) (d)	Surface Water	7/77	Metals/Inorganics	Including As, Cd, Cu, Pb, As, Zn, Ni, Hg	Zn, Cd, and Pb appear to be elevated in Canal Creek.
			Water quality parameters (c)	--	
	Sediment	7/77	Metals/Inorganics	Including As, Cd, Cu, Pb, As, Zn, Ni, Hg	Zn, Cd, Cu, Hg, and Pb are present in Canal Creek sediments at levels slightly elevated above background. Also elevated levels of pesticides and PCBs were found.
			Pesticides	Including chlorinated pesticides, organophosphates, and selected herbicides	
			PCBs	Aroclors 1242, 1248, 1254, 1260	
	Fish and clams (tissue unspecified)	7/77	Metals	As, Cd, Cu, Pb, Zn, Ni, Hg only	Metal levels found were below maximum levels safe for human consumption but Pb and Zn were elevated.
AEHA (1962) (e)	Surface Water	3/62 - 8/62	Water quality parameters	pH, DO, COD, BOD, and solids only	Study results suggested no significant impact on the Gunpowder River or Bush River.
			Inorganics	Chloride and nitrate only	
Rishel (1957) (e)	Surface Water	1957	Water quality parameters	pH, temperature, and DO only	Effluent from Canal Creek could be detected for several hundred yards along the eastern shore of the Gunpowder River.

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, pH, DO, silicate, oil and grease, turbidity, and bacteria counts.
(d) This study encompassed several study areas at Aberdeen Proving Ground. Only information related to Canal Creek is summarized here.
(e) Information for this study is summarized from discussions in AEHA (1989a).

TABLE 3-4

SUMMARY OF SITE INVESTIGATIONS

CARROLL ISLAND

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses Analytes	 Comments	Summary of Key Findings (a)
USGS (1990b) (b)	Groundwater	6/88 - 9/88	Metals/inorganics	Including Ca, Cl, Fe, Mg, Mn, P, Si, Na, SO4	Volatile organics detected in only a few samples. Elevated levels of Al, Br, Ba, Cl, Fe, Pb, Mn, K, Ag, Na, Tl, and Zn found.
			Water quality parameters (c)	--	
			Volatile organic compounds	--	
		4/89 - 5/89	Metals/inorganics	Includes priority pollutant metals (d)	
			Water quality parameters (c)	--	
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including organochlorine pesticides and organophosphates	
			PCBs	Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	
	Soil/Sediment	5/90 - 10/90	Metals/inorganics	Includes priority pollutant metals (d) except As	No results have been published yet.
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including organochlorine pesticides and organophosphates	
			PCBs	Aroclors 1016, 1221, 1242, 1248, 1254, 1260	

See footnotes at the end of table.

TABLE 3-4 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CARROLL ISLAND

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USGS (1990b) (b) (Cont.)	Surface water	10/88	Water quality parameters (c)	--	Volatile organics detected at various sites. Elevated levels of many metals including Al, Be, Cd, Ca, Cl, Cu, Fe, Mg, Mn, Ni, K, Ag, Na, and Zn.
		4/89 - 5/89	Metals/inorganics	Includes priority pollutant metals (d) except As, Sb, Hg, Pb, and Se	
			Water quality parameters (c)	--	
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including organochlorine pesticides and organophosphates	
			PCBs	Aroclors 1016, 1221, 1242, 1248, 1254, 1260	
USATHAMA (1983) (b,e)	Groundwater	12/77, 1/78, or 2/78	Volatile organics	TICs identified (f)	High levels of dissolved solids, TOC, and COD in many samples. Very high level of methylene chloride in one well. Chlorophenyl isocyanate was found in four wells.
			Base neutral organics	TICs identified (f)	
			Metals/inorganics	--	
			APG-specific chemicals	Including IMPA	
			Water quality parameters (c)	--	
	Soil (near surface)	11/77	Base neutral organics	TICs identified (f)	Trace levels of chlorinated and aromatic hydrocarbons were found. Naphthalene compounds found in both samples. Levels of contaminants detected were not environmentally significant and the contaminants were not detected in groundwater at the same sites.

See footnotes at the end of table.

TABLE 3-4 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CARROLL ISLAND

			Analyses		
Agency/Organization	Media Sampled	Sampling Period or Event	Analytes	Comments	Summary of Key Findings (a)
USATHAMA (1983) (b,e) (Cont.)	Surface water	3/78 (sampled twice)	Volatile organics	--	Migrating contaminant levels too small to have a measurable impact.
			Base neutral organics	--	
			Metals/Inorganics	--	
	Sediment	1977 and 1978	Base neutral organics	--	Saturated aliphatic hydrocarbons and a large variety of alcohols, aldehydes, ketones, esters, and carboxylic acids found at low ug/g concentrations. However, these are probably not due to activities at APG. TCPU was found on the northern and eastern sides of Carroll Island.
Ward (1979) (e)	Spotted turtles	1970-1975	Home range and population age	--	Home range and population age differences between the eastern and western halves of the Island indicated harmful but reversible local impacts from chemical agent testing.
Pinkham et al. (1976) (e)	Mammals	1970-1973	Species diversity and abundance	--	No evidence of adverse effects from chemical agent tests except possibly at woodlot #4 which shows the lowest density of the experimental (as opposed to control) areas.
Pearson and Bender (1973) (e)	Local ecology at the dredge spoils site	1972-1974	Effects of discharge from the dredge spoils site	--	Impact of discharge localized to Seneca Creek.
Worthley and Schott (1973) (e)	Woody flora	1971 and 1972	Floral diversity	--	76 species and 2 hybrids in 33 families found.

See footnotes at the end of table.

TABLE 3-4 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CARROLL ISLAND

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (e)
			Analytes	Comments	
Pearson and Ward (1972) (e)	Carp	August 1971	Carp kill investigated	--	Probable cause of death of 90-100 carp was a commercial fisherman's live-box found nearby.
Roelle and Slack (1972) (e)	Birds		Species distribution, abundance and diversity	--	Diverse avifauna present with no apparent effect from previous chemical testing.
Slack et al. (1972) (e)	Reptiles & Amphibians	1969-1971	Species diversity	--	Reptiles and amphibians are not affected by chemical agent testing on Carroll Island.
Speir (1972) (e)	Fish		Species abundance, diversity, seasonal cycles, and growth rate	--	Fish characteristic of a normal estuarine community.
Edwards et al. (1971) (e)	Tissues of selected wildlife species in the vicinity of Edgewood Arsenal	1969	Natural cholinesterase enzyme levels	--	Results unspecified.
Smrchek (1971) (e)	Zooplankton	1970	Species diversity	--	No evidence of environmental impact from testing activities on the island.
	Invertebrates	1970-1971	Species diversity	--	Abundant mixture found.

See footnotes on the following page.

TABLE 3-4 (Continued)

SUMMARY OF SITE INVESTIGATIONS

CARROLL ISLAND

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
Smrchek (1971) (e) (Cont.)	Soil-litter invertebrates	1970	Population evaluated	--	Previous testing had not affected soil-litter invertebrate populations.
Weimer et al. (1970) (e)	Aquatic species	Date unspecified	Agents/related compounds	VX and GD only Anticholinesterase activity	The 60 minute LC50 in Gunpowder River water was 215 mg/L for bluecrab, 0.1 mg/L for striped bass, 0.085 mg/L for white perch. The 60 minute LC50 for GD in Gunpowder River was 0.0057 for white perch. Analysis for anticholinestrase activity shows VX stable in Gunpowder River water with 44% of activity left after 29 days and 50% of GD activity gone within 6 hours.

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) This study encompassed several study areas at Aberdeen Proving Ground. Only information related to Carroll Island is summarized here.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.
(d) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(e) Information from this study is summarized from discussions in AEHA (1989a).
(f) Tentatively identified compounds (TICs) are chemicals identified during a library search of mass spectra. Here only spectra numbers are identified -- not the name of the compound.

3.2.5 GRACE'S QUARTERS

USGS performed a groundwater, surface water, sediment, and soil investigation at Grace's Quarters from 1988 to 1990 in conjunction with their work at Carroll Island. The previously described installation-wide assessment of the Edgewood Area by USATHAMA represents the only other environmental study performed at Grace's Quarters; this investigation included groundwater, surface water, sediment, and soil sampling. The USGS and USATHAMA studies are summarized in Table 3-5.

3.2.6 NIKE SITE

A summary of the previous investigation at the Nike Site, a geohydrologic study performed by AEHA, is presented in Table 3-6. This study was conducted from 1986 to 1990, and included sampling of groundwater, surface water, standing water in missile silos, soil gas, sediment, and soil, and encompassed both the launch and control areas. A radiation survey was also performed in both areas. Several previous studies of the site involved record searches, aerial photography interpretation, and similar activities, but provided no site-specific chemical data for use in risk assessment.

3.2.7 MICHAELSVILLE LANDFILL

The most detailed and comprehensive source of chemical data for the Michaelsville Landfill is a recent RI completed by USAEWES (1988-1990). This study included groundwater, seep, surface water, soil, soil gas (well head space sampling and methane sampling), and air sampling. Previous investigations included installation of eight monitoring wells and collection of groundwater samples in 1980 by the U.S. Army Corps of Engineers (COE), Baltimore District, and groundwater, seep, and surface water monitoring from 1979 through 1987 by AEHA, the State of Maryland Department of the Environment, and various private contractors.

Previous investigations at Michaelsville Landfill are summarized in Table 3-7.

3.2.8 PHILLIPS ARMY AIRFIELD

As indicated in Table 3-8, only very limited investigations have been performed at the Phillips site. AEHA conducted two rounds of groundwater monitoring at 10 wells in 1988 and 1989; a previous investigation performed by AEHA in 1984 also addressed groundwater contamination only. No soil, sediment, or surface water sampling has been conducted at the Phillips site. Also, investigations to date have focused strictly on the landfill area; other potential sources of contamination (e.g., "grease pits" and open-burning areas) have not been evaluated.

3.3 QUALITY ASSURANCE

Chemical data available for the APG baseline risk assessments was compiled from numerous studies, as outlined previously, and were collected by multiple government agencies according to different QA/QC protocols (e.g., USATHAMA QA requirements, EPA Contract Laboratory Program [CLP] protocols). In addition, data were gathered from the early 1970s through 1990, a period in which environmental sampling and especially analytical methods became increasingly sophisticated. In particular, detection limits for many compounds decreased several orders of magnitude, analytical instrumentation became much more sophisticated and accurate, and QA/QC practices became more

TABLE 3-5

SUMMARY OF SITE INVESTIGATIONS

GRACES QUARTERS

			Analyses		
Agency/Organization	Media Sampled	Sampling Period or Event	Analytes	Comments	Summary of Key Findings (a)
USGS (1990b) (b)	Groundwater	7/88 - 9/88	Metals/inorganics	Including Ca, Cl, Fe, Mg, Mn, P, Si, Na, SO4	No results have been published yet.
			Water quality parameters (c)	--	
		4/89 - 5/89	Metals	Includes priority pollutant metals (d) except As	
			Water quality parameters (c)	--	
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including chlorinated pesticides, organophosphates	
			PCBs	Aroclors 1016, 1221, 1242, 1248, 1254, 1260	
	Soil	5/90 - 10/90	Metals	Includes priority pollutant metals (d) except As	No results have been published yet.
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including chlorinated pesticides, organophosphates	
			PCBs	Aroclors 1016, 1221, 1242, 1248, 1254, 1260	
	Surface Water	10/88	Water quality parameters (c)	--	No results have been published yet.
			Volatile organic compounds	--	

See footnotes at the end of table.

TABLE 3-5 (Continued)

SUMMARY OF SITE INVESTIGATIONS

GRACES QUARTERS

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USGS (1990b) (b) (Cont.)	Surface Water	4/89 - 5/89	Metals	Includes priority pollutant metals (d) except As	No results have been published yet.
			Water quality parameters (c)	--	
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including chlorinated pesticides, organo-phosphates	
			PCBs	Aroclors 1061, 1221, 1242, 1248, 1254, 1260	
	Sediment		Metals	Includes priority pollutant metals (d) except As	No results have been published yet.
			Volatile organic compounds	--	
			Base neutral organics	--	
			Pesticides	Including chlorinated pesticides, organo-phosphates	
			PCBs	Aroclors 1061, 1221, 1242, 1248, 1254, 1260	
USATHAMA (1983) (b,e)	Groundwater	12/77, 3/78, or 4/78	Volatile organics	--	Very high levels of chloroform and trichlorofluoromethane were found.
			Base neutral organics	--	
	Soil (shallow sample)	One event (date unspecified)	Volatile organics	--	Naphthalene compounds and chlorinated biphenyls were found. A trace level of cyclohexanol found in this soil sample was also found in the groundwater sample taken here.
			Base neutral organics	--	
			APG-specific chemicals	Including white phosphorus, thiodiglycol	

See footnotes on the following page.

TABLE 3-5 (Continued)

SUMMARY OF SITE INVESTIGATIONS

GRACES QUARTERS

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses: Analytes	Analyses: Comments	Summary of Key Findings (a)
USATHAMA (1983) (b,e) (Cont.)	Surface Water	1976-1979 (Sampling events unspecified)	Volatile organics	--	Migrating contaminants were too small to have a measurable impact on Gunpowder River.
			Base neutral organics	--	
			Metals/inorganics	--	
			APG-specific chemicals	Including white phosphorus, thiodiglycol	
	Sediment	1976-1979 (Sampling events unspecified)	Volatile organics	--	TCPU was found in 27 of 33 locations in the Gunpowder River.
			Base neutral organics	--	
			Metals/inorganics	--	
			APG-specific chemicals	Including white phosphorus, thiodiglycol	

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) This study encompassed several study areas at Aberdeen Proving Ground. Only information related to Graces Quarters is summarized here.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.
(d) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(e) Information for this study is summarized from discussions in AEHA (1989a).

TABLE 3-6

SUMMARY OF SITE INVESTIGATIONS

NIKE SITE

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses: Analytes	Analyses: Comments	Summary of Key Findings (a)
AEHA (1990)	Groundwater	6/87, 10/87 or 11/87 (24 locations)	Volatile organics	--	Elevated levels of Ba found in many samples.
			Base neutral organics (and acid extractables)	--	Shallow groundwater in the control area is contaminated with low levels of trichloroethylene and 1,1,1-trichlorethane. The launch area is contaminated with low levels of trichloroethylene, 1,1,1-trichloroethane and trans-1,2-dichloroethylene.
			Metals/Inorganics	--	
			Radionuclides	--	Groundwater investigations at the launch area show that tetrachloroethylene in the surficial aquifer has moved downgradient a distance of at least 800 feet. Groundwater at the launch area also contains trans-1,2-dichloroethylene, and carbon disulfide.
			Pesticides	--	
			PCBs	--	
		6/88	Volatile organics	--	
		6/89 or 7/89 (Selected wells only)	Volatile organics	--	Acetone, bis(2-ethylhexyl)phthalate, methylene chloride and 2-ethyl-1-hexanol were detected in some samples.
	Soil	7/86 and 8/86	Organics	Hydrocarbon contamination by hydraulic fluid or fuel oil	Soils at the launch area contain trichloroethylene, 4-nitro-phenol, p-chloro-m-cresol and pentachlorophenol. Elevated levels of As, Cd, Hg, and Se were found. Radiasurvey findings indicated no radiation levels above background for the surface and subsurface soils in the three areas surveyed. It is not possible to conclude that no radioisotope containing electron tubes were buried on site. Soil in the control area contained bis(2,4,6-trichlorophenyl)urea and elevated levels of Hg and Se.
			Metals	--	
			Radionuclides	Beta and gamma emitters	
	Sediment	8/86 (3 samples)	Volatile organics	--	Sediment samples from the drainage ditches in the launch area contained elevated concentrations of total Pb, Ba, Cr, Cd and Se. Trace levels of tetrachloroethene, bis(2-ethylhexyl)phthalate and hexanedioic acid (diocyl ester) were found.
			Base neutral organics	--	
			Metals	--	

See footnote on the following page.

TABLE 3-6 (Continued)

SUMMARY OF SITE INVESTIGATIONS

NIKE SITE

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses: Analytes	Analyses: Comments	Summary of Key Findings (a)
AEHA (Cont.) (1990)	Surface water	8/86	Volatile organics	--	Volatile organics were not detected in the sample collected from the upper portion of Monks Creek.
	Soil Gas	7/86 and 8/86	Volatile organics	--	Trichloroethene, tetrachloroethene, chlorobenzene, chloroform, and 1,1,1-trichloroethane were detected.
	Soil Boring Groundwater	7/86 and 8/86	Volatile organics	--	Trans-1,2-dichloroethene, 1,1,1-trichloroethane, and trichloroethene were detected.
	Water in 6 Silos	7/86	Volatile organics Base neutral organics Metals/Inorganics Radionuclides	-- -- -- --	The 6 missile silos all contain some amount of water from ground seepage and surface run-in. Water from the silos contained elevated levels of Pb. Water from one silo contained 28 ug/L trichloroethene and another had 130 ug/L butylbenzylphthalate. Gross alpha and gross beta were detected.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.

-- = No comment.

TABLE 3-7

SUMMARY OF SITE INVESTIGATIONS

MICHAELSVILLE LANDFILL

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USAEWES (1990)	Groundwater	1/88 (8 samples)	Volatile organics	--	Elevated levels of chloride, Fe, ammonia nitrogen, and organophosphate were detected. With limited exceptions wells exceeded drinking water standards for chloride, Fe, Mn, and pH. Some non-drinking parameters were detected at low levels. Sb, Ca, Mg and Na were consistently detected but at levels below drinking water criteria. Ni was found below the human health advisory level with one exception.
			Base neutral organics	--	
		9/88 (32 samples)	Metals/inorganics	Including priority pollutant metals (b)	
		12/88 (22 samples)	Pesticides	Including chlorinated pesticides	
			PCBs	Aroclor 1016, 1221, 1232, 1242, 1248, 1254, and 1260	
		4/89 (25 samples)	Water quality parameters (c)	Including COD, TOC, and pH only	
	Seeps	5/88 (1 sample)	Volatile organics	--	At least one sample exceeds the water quality criteria or federal drinking water standards (current or proposed) Maximum Contaminant Level (MCL) for the following parameters: Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn, dieldrin, heptachlor, methoxychlor, Aroclor 1221, cis-1,2-dichloroethene, tetrachloroethene, and vinyl chloride.
			Base neutral organics	--	
		9/88 (1 sample)	Metals/inorganics	Including priority pollutant metals (b)	
		4/89 (4 samples)	Pesticides	Including chlorinated pesticides	
			PCBs	Aroclor 1016, 1221, 1232, 1242, 1248, 1254, and 1260	
		10/89 (4 samples)	Water quality parameters (c)	Including COD, TOC, and pH only	
	Surface water	5/88 3 samples	Volatile organics	--	Virtually no organic chemicals were detected in surface water samples. Elevated levels of As, Se, and K found. Fe, Mn, Ni, Ag, b-BHC, dieldrin, cis-1,2-dichloroethene, tetrachloroethene, and vinyl chloride were found to exceed Water Quality Criteria or current or proposed Federal drinking water standards MCLs.
			Base neutral organics	--	
			Metals/inorganics	Includes priority pollutant metals except chloride	
			Pesticides	Including chlorinated pesticides	
			PCBs	Aroclor 1016, 1221, 1232, 1242, 1248, 1254, and 1260	
			Water quality parameters (c)	Including COD and TOC only	

See footnotes at the end of table.

TABLE 3-7 (Continued)

SUMMARY OF SITE INVESTIGATIONS

MICHAELSVILLE LANDFILL

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
USAEWES (Cont.) (1990)	Soil	10/89 (4 samples)	Volatile organics	--	The few organic chemicals detected in the 2 cover soil samples collected from the landfill were similar to levels detected in background and/or were detected in blanks with the exception of acetone which was detected at 41 mg/kg in a cover sample but not in background or blank samples. In addition, the inorganic chemicals and pesticides detected in the soil cover samples were similar to those detected in background soil samples.
			Base neutral organics	--	
			Metals/inorganics	Including Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Si, Ag, Tl, and Zn only	
			Pesticides	Including chlorinated pesticides	
			PCBs	Aroclors 1221 and 1254	
	Head space of all wells	7/88	Light hydrocarbons	Methane, ethane, ethylene, propane, propylene, butane	The gas present was only in new wells and was mostly methane with low levels of other analytes. A maximum methane level of 5,971 ppm (less than 1%) was found in the five deep wells sampled in July 1988.
		8/88	Petroleum hydrocarbons	--	No appreciable levels were detected.
	Wells	2/89, 3/89 and 4/89 (12 wells, each sampled on each sampling date)	Methane	--	Elevated levels of methane found. A maximum concentration of 51.8% of methane and 100% of the lower explosive limit (LEL) was found in all of the wells installed in the landfill itself. In addition, 100% of the LEL was seen in two wells north and northwest of the landfill.
	Air	3/89 and 4/89	Volatile gas	--	No gases were detected.

See footnotes at the end of table.

TABLE 3-7 (Continued)

SUMMARY OF SITE INVESTIGATIONS

MICHAELSVILLE LANDFILL

			Analyses		
Agency/Organization	Media Sampled	Sampling Period or Event	Analytes	Comments	Summary of Key Findings (e)
AENA (d) State of ND Various Contractors (Assumed unpublished)	Groundwater	6/80 - 3/87 (8 wells sampled at 17 different sampling events)	Volatile organics	Specifics-analytes vary with sampling event	Two wells consistently showed benzene concentrations above the detection limit. Consistently high chloride levels were found in one well and 3 others had concentrations greater than the background range but less than 250 mg/L. Chromium detected at low levels periodically. Selenium not detected. Elevated levels of Ca, Mg, and Na found for a few wells. Ni usually below 0.100 mg/L except for some readings slightly above that level twice. Historically 3 wells show elevated levels of K. 3 wells one time found to have Tl at the detection limit or slightly above.
			Base neutral organics	Specifics-analytes vary with sampling event	
			Metals/inorganics	Specifics-analytes vary with sampling event	
			Water quality parameters (c)	Specifics-analytes vary with sampling event	
			Pesticides	Specifics-analytes vary with sampling event	
			PCBs	Specifics-analytes vary with sampling event	
	Seep	Fall 1986 (2 sites)	Metals/inorganics	Includes priority pollutant metals and inorganics (b) except Sb, Be, and Tl	Concentrations of iron exceed the current MCL of 0.3 mg/L. Manganese concentrations exceed the current MCL of 0.05 mg/L.
			Water quality parameters (c)	--	
	Surface water	1979 - 1987 (21 sampling events)	Metals/inorganics	Includes priority pollutant metals and inorganics (b) except Sb, Be, and Tl.	Concentrations of iron, manganese, and lead were elevated.
			Water quality parameters (c)	--	
AENA (1984)	Groundwater	10/83 - 1/84	Volatile organics	--	No National Interim Primary Drinking Water Regulation standards are exceeded. One well showed high specific conductivity and that well and one other show high chemical oxygen demand. Triethyl phosphate and cryoflex are detected in two wells. Acetone, toluene, some ketones, and diethyl ether are detected in one well and benzene and chlorethane are detected in another. Overall the organic contamination is confined to the Michaelsville Landfill.
			Base neutral organics	--	
			Metals	As, Be, Cd, Cr, Pb, Hg, Ag only	
			Pesticides	Including chlorinated pesticides, organophosphates, and herbicides	
			PCBs	Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	
			Water quality parameters (c)	Including pH, specific conductivity, chemical oxygen demand, temperature	
			Miscellaneous	Grease and oil	

See footnotes on the following page.

TABLE 3-7 (Continued)

SUMMARY OF SITE INVESTIGATIONS

MICHAELSVILLE LANDFILL

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
COE (1980) (e)	Groundwater	Assumed 1979 or 1980	Non-toxic substances	No munitions, pesticides, PCBs or hydrocarbons	Water on the downgradient side of the landfill has noticeably higher concentrations of TDS, BOD, Fe, Pb, Ni, Na, and chlorides.

-- = No comment.
COE = U.S. Army Corps of Engineers.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.
(d) Information for this study is taken from summaries in USAEWES 1990.
(e) This information is taken from summaries in ESE 1981.

TABLE 3-8

SUMMARY OF SITE INVESTIGATIONS

PHILLIPS LANDFILL

Agency/Organization	Media Sampled	Sampling Period or Event	Analyses		Summary of Key Findings (a)
			Analytes	Comments	
AEHA (1988 & 1989b) (Phases 1 and 2)	Groundwater	4/88 - 5/88 (10 wells)	Volatile organics	--	The first sampling round showed higher TDS levels than the second, probably because of disturbance during well installation. Low levels of benzene, methylene chloride, trichloroethene, vinyl chloride and trans-1,2-dichloroethene were detected. Elevated levels of Cd, Fe, and Mn were found.
		11/88	Metals/inorganics	Including priority pollutant metals/inorganics (b) except Sb, Be, Cu, Ni and Tl	
			Water quality parameters (c)	--	
AEHA (1984)	Groundwater	1/84	Volatile organics	--	The only organics that were detected were phthalates, common laboratory contaminants. Of the inorganics, only Ba and Pb were detected, both slightly above their detection limits. Grease and oil were detected in 5 of 8 wells.
			Base neutral organics	--	
			Metals	As, Ba, Cd, Cr, Pb, Hg, Ag only	
			Pesticides	Including chlorinated pesticides, organophosphates, and herbicides	
			PCBs	Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	
			Water quality parameters (c)	Including pH, specific conductivity, chemical oxygen demand, temperature	
			Miscellaneous	Grease and oil	

-- = No comment.

(a) Key findings are as reported by the authors. These findings are not necessarily representative of Clement International Inc.'s conclusions for these studies.
(b) Priority pollutant metals and inorganics are: Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Tl, Zn, and CN.
(c) Water quality parameters, as defined here, include parameters such as BOD, COD, TOC, TSS, TDS, silicate, oil and grease, turbidity, and bacteria counts.

rigorous, including the use of matrix and surrogate spikes, method and field blanks, and reference standards.

Based on these factors, data from a study completed in 1975 is not comparable in most instances to data collected for the same site, compound, and environmental medium in a 1989 study, not only because of the time period that has elapsed between sampling events, but also because of analytical and QA considerations. Thus, as an initial step in performing a QA evaluation of available data that would potentially be used in the baseline risk assessments, ICF KE and Clement made the decision that data collected prior to 1985 did not represent "modern" information, either in terms of representativeness in the current time frame or with regard to acceptable analytical and QA protocols. All data from pre-1985 studies were therefore used only as qualitative indicators of site contamination in the risk assessments; quantitative evaluations and statistical evaluation were performed only with information collected during or after 1985. Thus, the most recent studies by USGS, AEHA, and USAEWES (see Section 3.2) encompass the majority of quantitative information used for the risk assessments.

Although data from the 1985-1990 time frame were generally collected using modern analytical methods, samples were collected and analyzed by different government agencies according to varying QA protocols. Exact procedures and details varied among individual studies; however, in general, USATHAMA and USGS data were collected according to the requirements of the USATHAMA QA Plan (USATHAMA 1987), whereas USAEWES and AEHA followed EPA CLP methods and QA requirements. Specific QA problems with each of these programs, as well as difficulties in retrieving and utilizing data from individual studies, are described in the following subsection.

3.3.1 USATHAMA IRDMS AND USGS DATA

The predominant data sources for many of the APG-EA sites (O-Field, J-Field, Canal Creek, Carroll Island, and Grace's Quarters) are USGS studies that have been performed using USATHAMA protocols, with samples analyzed by USATHAMA-certified CLASS program laboratories and analytical data entered into the IRDMS. Problems that Clement has encountered with the use of these data in the baseline risk assessments include the following:

- The USATHAMA data base does not use many of the standard EPA qualifiers for (1) analytes for which method or field blank contamination is suspected; or (2) concentration values that have been estimated below the laboratory's certified reporting limit (CRL). These types of data are typically given less weight in risk assessment because of uncertainties associated with them; however, because no differentiation was possible, a decrease in the overall quality of the data set must be assumed.

- Tentatively identified compounds (TICs), which are analytes not included on the standard target compound list for a given method but identified through mass spectra library matches, are not clearly identified in the IRDMS (i.e., it is impossible to differentiate between a target compound and a TIC, even though there is considerably more uncertainty associated with both the identity and concentration value of the TIC). This factor also decreases the overall quality of the available data and adds uncertainty to the risk assessments.

- A non-specific "Method 99" designation is used for IRDMS data that is considered suspect; however, the non-specificity of this qualifier greatly limits its usefulness, because it can indicate anything from gross cross-contamination to the fact that data simply were generated by non-USATHAMA methods. This designation therefore is applied to concentration values that may have been generated by methods that were completely acceptable from a substantive viewpoint, but did not meet USATHAMA protocols; conversely, some "Method 99" information is probably highly suspect. Because the "Method 99" qualifier has been assigned to a great deal of APG data, we were forced to incorporate this type of information into the risk assessments, again adding uncertainty and diminishing the overall quality of the data set.

- Although USATHAMA maintains standard protocols for collection of samples (e.g., VOC samples are never filtered, groundwater samples for metals analyses are always field-filtered), these protocols are often overruled at the request of regulatory agencies or to meet project-specific objectives. The IRDMS does not permit differentiation between total and dissolved concentrations (i.e., unfiltered and filtered samples), which are potentially very important in risk assessment. For example, contaminants sorbed to suspended particulate matter in surface water are less bioavailable to many aquatic organisms, and considering these concentrations as part of the dissolved fraction will tend to over-estimate risks.

- Duplicate and split samples are not designated in the IRDMS, again potentially diminishing the overall quality of the APG data set.

Some USGS data used in the risk assessment (predominantly Old O-Field data and some groundwater and surface water data for Canal Creek) was not entered into the IRDMS, but was obtained directly from the USGS Towson office in the form of open-file reports, data reports, letter reports, and unpublished data files. These data were generally gathered according to USATHAMA QA protocols with some specific QA/QC information available (e.g., TICs were identified, duplicates were identified, sampling procedures were outlined in detail); however, Clement found that even for these more recent and detailed data sets, some information was inevitably lost in data transfer. For example, sample lots were no longer designated in data reports; therefore, although field and method blank data were available, they could not be matched with specific sample sets to evaluate whether blank contamination was significant. In addition, information on specific analytes, detection limits, and methods was sometimes lost in translation of summarized information from hydrogeologic investigations to a format useable for the risk assessments. Based on these problems, most recent USGS data, even if obtained directly from the agency rather than through the IRDMS, has significant QA uncertainties associated with it.

3.3.2 AEHA DATA

As noted in Section 3.2, AEHA studies were the primary sources of chemical data for the Nike and Phillips Army Airfield study areas, and also provided supplementary information at nearly all of the other areas. AEHA chemical concentration data were generated mostly using EPA methods; however, most of these data were available to Clement only in summarized hard-copy format in reports and appendices. For most of this information, it was difficult to determine what QA measures had been taken, because samples had been analyzed by AEHA's own laboratory as well as private subcontractor laboratories, with EPA CLP protocols apparently being followed to varying degree in different investigations. In addition, data summaries often did not identify all of the specific analytes that were measured, and contained little or no information on detection limits. In some instances, the analytical methods used to obtain the data were not identified.

Overall, the AEHA data utilized in the baseline risk assessments is lacking in QA documentation and does not provide the same level of defensible, fully validated data that would be afforded by strict adherence to EPA CLP QA requirements. Although data quality and documentation varies among individual AEHA studies (with the Nike site data being most complete), many of the same problems noted previously regarding loss of data quality during summarization (e.g., loss of blank data; unspecified analytes, detection limits, and methods) also apply to this information.

3.3.3 USAEWES DATA

USAEWES data for the Michaelsville Landfill were generated using EPA CLP methods and were fully validated in accordance with CLP QA protocols. These data were provided to Clement as a complete set containing information on all detected and non-detected compounds, blank data, and QA/QC sample analyses. The USAEWES data for Michaelsville Landfill are therefore considered to meet the requirements of EPA Level 4 information, and are of sufficient quality for performing a baseline risk assessment in accordance with EPA guidance.

3.4 SUMMARY

Based on the above-outlined factors, we generally believe that, although data from individual USGS and AEHA studies and the APG IRDMS data base vary somewhat in quality, the overall data set from these sources is substandard compared to EPA CLP-generated and validated data which would typically be used to perform a CERCLA site risk assessment. Only the Michaelsville Landfill data set from USAEWES represents defensible, fully validated EPA Level 4 information that would be considered acceptable for performing a baseline risk assessment without additional caveats and qualifiers.

The variability in data quality for most of the study areas adds greatly to the uncertainty that is already inherent to the baseline risk assessments. Uncertainties regarding data quality generally require that conservative assumptions be made (e.g., that methylene chloride is present in a sample because of site-related contamination, rather than because of field blank contamination), resulting in the potential over-estimation of risks in some instances. Thus, uncertainty factors and potentially over-conservative assumptions related to data quality problems must be taken into account in evaluating the findings and conclusions of the risk assessments presented in the later chapters of this report. Additional information on QA problems, uncertainties, and data gaps for individual sites are discussed in greater detail in the following chapters.

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4.0 BASELINE RISK ASSESSMENT METHODOLOGY

The human health and ecological assessments undertaken in this report generally follow EPA guidance (EPA 1986a,b,c, 1988a, 1989a,b,c,d, 1990) and are based entirely on the sampling data discussed in the previous chapter. Although risks are quantitatively evaluated to the extent possible for each of the study areas under consideration, the ability to quantify or even evaluate risks is constrained to a large degree by the adequacy of the data supporting such estimates. For example, many of the investigations conducted at APG study areas were focused hydrogeologic investigations that were not designed to provide data relevant to risk assessment or to provide a systematic or exhaustive characterization of chemical contamination in all media. Consequently, quantitative risk estimates cannot always be made for each study area or for each medium. In these cases, risk evaluations are limited to qualitative or semiquantitative statements of potential impacts.

Because the data available for this assessment have been collected over many years by different groups and under varying sampling and analytical protocols, the quality of the data is variable. An attempt has been made to compensate for the potentially differing quality of the data by using data that have been subjected to USATHAMA validation procedures (when available) and data from more recent studies (1985 to present). The assumption behind the latter criterion is that data from more recent studies have been collected under the increasingly stricter protocols dictated by the regulatory climate. Overall, the data used for this assessment are considered to be of sufficient quality to provide preliminary estimates of risks for most study areas. Additional data and site characterization may be needed to generate more definitive estimates of risk for most study areas.

The risk assessment for each study area consists of the following sections:

- Background Information
- Selection of Chemicals of Potential Concern
- Human Health Risk Assessment
- Ecological Assessment
- Uncertainties
- Principal Data Gaps
- Summary and Conclusions

The principal steps and methodologies used for each of these sections are discussed below.

4.1 BACKGROUND INFORMATION

This section provides general background information on the study area with respect to its location, physical setting, and history.

4.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

The first step in a risk assessment is to collect, summarize, and analyze site data to identify the chemicals present at the site that will be the focus of the risk assessment. Chemicals selected for further evaluation are termed "chemicals of potential concern" and are defined as those chemicals that are present because of past activities at the site. Therefore, chemicals that are definitively associated with sampling or laboratory artifacts or naturally occurring chemicals that are within background levels are not selected as chemicals of potential concern. The procedures used to summarize available data and to screen data for the selection of chemicals of potential concern are discussed below.

4.2.1 DATA SUMMARY PROCEDURES

The data used in this risk assessment were (1) derived directly from the USATHAMA database (IRDMS) or (2) derived directly from published and unpublished study reports and project files.

The following procedures are used to summarize data for the individual study areas:

- Data were summarized by environmental medium (e.g., groundwater, soil).

- For data summarized from study reports and files, site data were compared to blank (laboratory, field, and trip) concentration data as available. (Blank data were not available for all study areas.) If the detected concentration in a site-related sample is less than 10 times (for common laboratory contaminants) or 5 times (for all other compounds) the maximum detected concentration in the corresponding blank sample, the concentration reported for the site-related sample was rejected and not included in the risk assessment.

- Frequency of detection was calculated as the ratio of the number of detects over the number of sample locations. Multiple samples collected from the same sample location were not treated as independent samples.

- Concentration data from multiple samples from the same sample location taken at different times were averaged. If a chemical was detected in one or more sampling rounds at a particular sample location and not in others, the average concentration for the sample location was calculated by averaging the detected concentration(s) with one-half of the detection limit of the nondetect(s). The value of one-half of the detection limit was commonly assigned to nondetects for the purposes of averaging because the actual value can be between zero and a value just below the detection limit. Split and duplicate samples (collected at the same time) for a given sampling point were also treated in this manner.

- Because there are varying chemical- and sample-specific detection limits, even within one medium, samples in which a chemical was not detected were compared to the maximum detected concentration for that chemical in a given medium to determine if one-half of the detection limit for the nondetect should be included in calculating the average (either for a given sample point or for a given medium). If the detection limit for a nondetect sample was two or more times higher than the maximum detected concentration in that medium, the sample was not included in the calculation of the average for that chemical. This was done to prevent the average from being artificially biased upwards by high detection limits. (There is some uncertainty associated with this approach because high detection limits may result in a chemical not being observed when it was actually present [i.e., false negatives].)

- Data for polycyclic aromatic hydrocarbons (PAHs) were summarized separately for carcinogenic and noncarcinogenic PAHs. The classification system developed by the International Agency of Research on Cancer (IARC 1983) was used to classify PAHs as carcinogenic or noncarcinogenic.

- To calculate the concentrations of carcinogenic and noncarcinogenic PAHs, the concentrations of each member of each class were first summed within each separate sample to obtain total carcinogenic and total noncarcinogenic PAH concentrations for that sample. One-half of the sample-specific detection limit was used for nondetects when calculating the total concentration of carcinogenic and noncarcinogenic PAHs for a given sample.

- A similar approach was used to calculate total concentrations of polychlorinated biphenyls (PCBs) and DDT and its metabolites.

- Tentatively identified compounds (TICs) were summarized separately from other site-specific chemicals. TICs, which are chemicals identified during a library search of mass spectra, were not included in the analyte list for a specified analysis but show up as additional peaks in the laboratory analysis. Because of uncertainties regarding the identity and concentration of TICs, these data generally were not used to make quantitative assessments of risk. In this report, TIC data were summarized separately from other site data and used qualitatively in the risk assessment where possible. In those situations in which TICs were selected for quantitative evaluation, the uncertainties associated with such an evaluation are noted.

Summary sampling data for each study area are presented by medium and by source area (as appropriate). Summary chemical data consist of the frequency of detection, the range of concentrations detected in site-related samples, and the range of concentrations reported in site-related or regional background samples. Summary data are then used to select chemicals of potential concern.

4.2.2 DATA SCREENING PROCEDURES

In selecting the chemicals of potential concern, the summary data were first screened to eliminate chemicals that occur naturally in the environment and that are present at levels associated with background concentrations. This determination is generally made only for inorganic chemicals only, because few potentially hazardous organic chemicals occur naturally. The exception to this is PAHs, which are ubiquitous in the environment, principally as a result of incomplete combustion of organic materials. If PAHs were present at a particular study area, their concentrations were compared to typical background levels to determine the site-relatedness of the concentrations detected at the study area. Organic chemicals that are not ubiquitous components of the environment were compared to background concentrations as available but were not eliminated from evaluation in the risk assessment.

According to EPA (1985) guidance, the Cochrans' approximation to the Bohrans-Fisher t-test should be used to determine whether chemical concentrations detected at the site are within or elevated above background levels. This test was used to evaluate background concentrations for those study areas and media where a sufficient number of samples was available (at least three upgradient and three downgradient samples).

If too few samples were available for statistical analyses, an inorganic chemical was considered to be elevated above background if the maximum detected on-site concentration exceeds the range of detected background concentrations (if more than one background sample was available) or exceeds the single reported background value by a factor of two. The factor of two, which is arbitrary, was used to reflect the variability in levels of naturally occurring chemicals. The factor of two is conservative because concentrations of naturally occurring chemicals can vary by more than an order-of-magnitude.

If a chemical was not detected in background samples but was detected in site samples (even at a concentration below the limit of detection achieved for the background sample), it was assumed to be elevated above background. This is a conservative approach that could result in chemicals being evaluated in the risk assessment that are actually present at naturally occurring levels.

In the absence of site-specific background data (which is typical for most APG study areas and media), local, regional, or national background levels were used. The most specific data available were used; local data were selected preferentially over regional data, which were selected over national data. However, use of any data that are not site specific could result in incorrect conclusions regarding the site-relatedness of a particular chemical, especially given the potentially variable and unique groundwater and surface water chemistry of the coastal and estuarine environment of APG. Tables 4-1 through 4-5 present background chemical data for soil (regional data), groundwater (national data), surface water (local data), and sediment (local and regional data).

An additional screening step was applied to inorganic chemical data to eliminate from further evaluation chemicals known to be of low toxicity to humans and to wildlife. These low toxicity chemicals are bromide, calcium, chloride, magnesium, nitrogen, kjeldahl nitrogen, phosphorus, potassium, sodium, and titanium. Summaries of the human health toxicity of these chemicals are presented in Appendix B. Ecological toxicity profiles for these chemicals are not provided because of the paucity of relevant toxicity data.

After these screening steps, an additional screening step was applied if the number of organic or inorganic chemicals of concern for an area exceeded 15. Under this step, chemicals were eliminated from evaluation if they were detected infrequently and at low concentrations. The selection of chemicals of concern at this screening step is discussed in the text of each risk assessment where applicable. This further screening step was conducted to make the risk assessment for each study area less cumbersome and to focus on the principal risks for a given study area. This screening step is regarded as appropriate for this assessment because the primary purpose of this risk assessment is to provide preliminary evaluations of risk to help focus additional investigations in each study area, rather than to provide definitive characterizations of the total risk associated with a given study area.

The output of this step in the risk assessment is a list, by media, of the chemicals of potential concern selected for evaluation for each study area. Another list was generated chemicals potentially present at the site but not detected in the sample analyses conducted to date. This list was based on historical waste disposal information together with information on the likely chemical fate and transport of waste constituents. These lists were used to identify other potential exposures at the site, and to identify potential gaps in the sampling data, either with respect to environmental media not sampled or chemicals not included in analyses to date. Data gaps have more or less significance depending on the potential for exposure, and therefore risks, that a particular area presents. This information was considered in the discussion of data gaps that follows the risk assessment for each area.

TABLE 4-1

ELEMENTS DETECTED IN SURFICIAL SOILS IN
BALTIMORE COUNTY, MARYLAND (a,b)

(Concentrations reported in mg/kg)

Chemical	Concentration
Aluminum	7.0E+04
Antimony	<1.00
Arsenic	6.0
Barium	500
Beryllium	2.0
Boron	20
Bromide	0.90
Calcium	1.8E+03
Cobalt	20
Chromium	70
Copper	70
Fluoride	400
Iron	7.0E+04
Lead	20
Mercury	0.05
Magnesium	7.0E+03
Manganese	500
Nickel	30
Potassium	2.0E+04
Selenium	0.10
Sodium	3.0E+03
Strontium	50
Sulfur	<800
Thorium	13
Tin	2.7
Titanium	5.0E+03
Zinc	1.1E+06

(a) Data from Boerngen and Shacklette (1981).

(b) Location is Rt. 45, 2 mi north of Hereford, approximately 25 miles northwest of APG. Soil description is yellow silt. Samples collected September, 1972.

TABLE 4-2

TYPICAL CHEMICAL CONCENTRATIONS IN GROUNDWATER NATIONWIDE (a)

(Concentration reported in ug/L)

Chemical	Concentration
Aluminum	100
Antimony	100
Arsenic	100
Barium	100
Beryllium	1.0
Bromide	100
Cadmium	100
Calcium	1,000,000
Chloride	1,000,000
Chromium	100
Cobalt	100
Copper	100
Fluoride	10,000
Iron	10,000
Lead	100
Magnesium	1,000,000
Manganese	100
Mercury	0.50 (b)
Nickel	100
Nitrate	10,000
Potassium	10,000
Phosphate	100
Selenium	100
Silver	1.0
Sodium	1,000,000
Sulfate	1,000,000
Thallium	1.0
Titanium	100
Tin	1.0
Vanadium	100
Zinc	100

(a) Data from Walton (1985), except as noted. Data are for dissolved chemical concentrations and represent the upper end of the range of typical background concentrations.

(b) Data from EPA (1986d).

TABLE 4-3

CONCENTRATIONS OF SELECTED INORGANIC CHEMICALS IN BACKGROUND SURFACE WATERS NEAR APG (a)

(Concentrations reported in mg/L)

	Concentration Range (b)			
Chemical	Foster Branch (c)	Tributaries of Otter Point Creek (d)	Cranberry Run (e)	Across All Sites (f)
Calcium	14 - 14	4.4 - 11	8.5 - 10	4.4 - 14
Chloride (Total)	26 - 26	12 - 20	22 - 46	12 - 46
Fluoride	0.1 - 0.1	0.1 (g) - 0.2	0.1 (h) - 0.1	0.1 - 0.2
Iron (Total)	1 - 1	0.25 - 2.7	0.23 - 0.74	0.23 - 2.7
Iron	0.53 - 0.53	0.015 - 0.23	0.036 - 0.24	0.015 - 0.53
Magnesium	4.3 - 4.3	2 - 5.6	5.6 - 7.1	2 - 7.1
Manganese (Total)	0.1 - 0.1	0.3 - 0.7	0.3 - 0.13	0.1 - 0.7
Manganese	0.1 - 0.1	0.01 - 0.082	0.023 - 0.076	0.01 - 0.1
Nitrate and Nitrite	0.8 - 0.8	0.1 - 2.2	0.8 - 5.3	0.1 - 5.3
Potassium	3 - 3	1.1 - 2.5	1 - 2.8	1 - 3
Sodium	16 - 16	6.7 - 12	13 - 21	6.7 - 21
Sulfate (Total)	21 - 21	10 - 17	7 - 16	7 - 21

(a) Information obtained from the STORET database, U.S. Environmental Protection Agency, Region III. Received from Charles Kanetsky, Environmental Services Division.

(b) Value is dissolved metal concentration unless otherwise noted. Total concentrations are provided when available.

(c) Foster Branch is located just west of the western boundary of APG. Foster Branch is a tributary of the Gunpowder River.

(d) Otter Point Creek is located north of APG and slightly north of the Town of Edgewood. Otter Point Creek is a tributary of the Bush River.

(e) Cranberry Run is located north of the Aberdeen area of APG, slightly north of the Town of Perryman. Cranberry Run is a tributary of Church Creek which flows into the Bush River.

(f) Concentration range for Foster Branch, Otter Point Creek tributaries and Cranberry Run is used in this report for background comparisons.

(g) For 1 of 11 observations the actual value is known to be less than 0.10.

(h) For 3 of 7 observations the actual value is known to be less than 0.10.

TABLE 4-4

CONCENTRATIONS OF TRACE METALS IN CRANBERRY RUN NEAR APG (a,b,c)

(Concentration reported in ug/L)

Chemical	Concentration (d)
Aluminum	<10
Antimony	<1
Arsenic	<1
Barium	74
Beryllium	<0.5
Cadmium	<1
Chromium	42
Cobalt	<1
Copper	1
Lead	5
Mercury	0.1
Molybdenum	<1
Nickel	6
Selenium	<1
Silver	<1
Stronium	70
Zinc	75

(a) Information obtained from the STORET database, U.S. Environmental Protection Agency, Region III. Received from Charles Kanetsky, Environmental Services Division.

(b) Trace metal concentration data were available for only one sample location.

(c) Cranberry Run is located north of the Aberdeen area of APG, slightly north of the Town of Perryman. Cranberry Run is a tributary of Church Creek which flows into the Bush River.

(d) Value is the dissolved metal concentration. Total metal concentrations not available.

TABLE 4-5

SEDIMENT CHEMICAL CONCENTRATIONS FROM THE BUSH AND GUNPOWDER RIVERS AND THE CHESAPEAKE BAY

(Concentrations reported in mg/kg)

Chemical	Concentration Range			
	Bush River (a,b)	Gunpowder River (a,b)	Bush/Gunpowder River Stations Combined (c)	Chesapeake Bay (d,e)
Inorganic Chemicals:				
Aluminum	5.8	4.4 (f)	4.4-5.8	--
Antimony	--	--	--	2.5-4.0
Arsenic	34-46	14-28	14-46	17-23
Cadmium	0.005-0.15	0.005-1.1 (g)	0.005-1.1	0.59-0.92
Chromium	69-69	50-60	50-69	110-200
Copper	43-45	41-43	41-45	48-65
Iron	41,000-45,000	40,000-42,000	40,000-45,000	--
Lead	42-66	46-52	42-66	68-74
Manganese	1,500-3,400	1,000-1,300	1,000-3,400	--
Mercury	0.10-0.24	0.23-0.30	0.1-0.3	0.21-0.30
Nickel	54-57	37-44	37-57	56-87
Selenium	--	--	--	0.92-1.3
Silver	--	--	--	0.59-0.67
Tin	--	--	--	3.1-7.9
Zinc	200-220	200-200	200-220	300-400
Organic Chemicals (h):				
PAH (Total)	--	--	--	3.8-6.4
Non-DDT Chlorinated Pesticides	--	--	--	0.005-0.01
DDT (Total)	--	--	--	0.007-0.014
PCBs (Total)	--	--	--	0.09-0.12

(a) Data from the Maryland Chesapeake Bay Toxicant Monitoring Program and received from the Maryland Department of the Environment, Chesapeake Bay and Special Projects Program. Received from Richard A. Eskin.
(b) Range of concentrations at one monitoring station over two years, 1988 and 1989. Bush River samples collected near Gum Point. Gunpowder River samples collected near Oliver Point.
(c) The concentration range for the Bush and Gunpowder River Stations is used in this report for background comparisons. If data are not available for either of these stations, data from the Chesapeake Bay are used.
(d) Data from NOAA (1988). The data have been normalized by dividing the raw concentration in a composite by the fraction (by weight) of sediment particles in the composite which are less than 64 um in diameter (fine grained or silt and clay).
(e) Range of concentrations from three stations located near the Chesapeake Bay Bridge and Annapolis.
(f) No data for 1989.
(g) No data for 1988.
(h) For the NOAA data, concentrations of individual chemicals within the categories of DDT and its metabolites, PAHs, chlorinated pesticides other than DDT, and PCBs were summed to obtain a total concentration.

-- No data available

4.3 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment is divided into three primary sections: exposure assessment, toxicity assessment, and risk characterization. The methods used to evaluate human exposure and toxicity and to characterize risks are discussed below.

4.3.1 HUMAN EXPOSURE ASSESSMENT

An exposure assessment was conducted to identify the potential ways by which human populations may be exposed to chemicals from the site (exposure pathways) and to provide quantitative/qualitative estimates of those exposures.

4.3.1.1 Exposure Pathway Determination

An exposure pathway (i.e., the sequence of events leading to contact with a chemical) generally consists of four elements:

(1) A source and mechanism of chemical release to the environment;

(2) A retention or transport medium for the released chemical;

(3) A point of potential human contact with the contaminated medium (i.e., the exposure point); and

(4) A route of exposure (e.g., inhalation).

Only complete exposure pathways are evaluated in a risk assessment. An exposure pathway is considered complete only if all the above four elements are present. As part of this analysis, the source and fate and transport of chemicals were first considered. Then, human populations potentially exposed to contaminated environmental media were identified based on land use information. Potentially exposed populations can be of three general types: residential, industrial/commercial,[1] and recreational. The three principal routes by which human populations can be exposed to chemicals in environmental media are ingestion, inhalation, and dermal contact.

A list of potential exposure routes by exposure medium is presented below. This information is used in conjunction with information on land use and potentially exposed populations to identify potential exposure pathways for evaluation.

Groundwater

- Ingestion and/or dermal contact with chemicals in groundwater used as water supply.

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[1] Workers involved in remedial investigation work are not considered in this risk assessment. Potential exposures and risks to these individuals are evaluated by the APG Health and Safety Office for each proposed activity.

Surface Water

- Ingestion and/or dermal contact with chemicals in surface water used as a water supply or while swimming, wading, or involved in other activities that involve water contact.

Air

- Inhalation of chemicals in the vapor phase or adsorbed to particulates. Air contaminants can originate from groundwater and surface water (vapors), or soil and sediment (dusts).

Soil/Sediment/Dust

- Ingestion and/or dermal contact with soil, sediments, or dust.

Food

- Ingestion of chemicals that have bioaccumulated in vegetation, aquatic life, game (e.g., deer), and/or domesticated animals (e.g, cows).

All complete exposure pathways were evaluated either quantitatively or qualitatively in this risk assessment unless:

- A screening analysis indicates that the exposure resulting from one pathway is much less than that from another pathway involving the same medium at the same exposure point;

- The potential magnitude of exposure from the pathway is low based on chemical concentration data or other factors, such as land use;

- The probability of exposure is very low, and the potential risks associated with the occurrence are not high (if potentially catastrophic consequences [e.g., acute lethality] are associated with exposure, the pathway was evaluated even if the probability of occurrence is low); or

- The probability of exposure is very low, and the value of the resource (e.g., value of groundwater as a drinking water source) is not high.

In evaluating potential human exposure pathways, both current and possible future land use were considered. For many of the study areas at APG, however, there are very few ways in which human populations could be exposed to contaminated environmental media under current land-use conditions (i.e., there are very few complete exposure pathways). As discussed in the exposure assessments for each study area, it is possible that the future use of some areas may differ from current use. These possible future land-use pathways, for the most part, consist of additional worker exposures as distinct from exposures under residential or recreational land-use scenarios. Future residential use of APG is not considered plausible.

In selecting future land-use pathways for evaluation, the potential for groundwater to be used as a drinking water source was evaluated according to EPA (1986e) draft guidance on groundwater classification. In making these determinations, the quality of the uncontaminated aquifer was considered. It is important to note, however, that groundwater associated with some study areas (in particular, Canal Creek, O-Field, and J-Field) may be so contaminated that it is not technologically or economically feasible to remediate these aquifers to meet drinking water standards using conventional water treatment technologies.

Using the criteria outlined in EPA's (1986e) draft guidance, groundwater at each of the eight study areas could be considered to be Class IIB groundwater. Class IIB groundwater is considered a potential source of drinking water; it is defined as groundwater that (1) can be obtained in sufficient quantity to meet the needs of an average family (i.e., 150 gallons per day); (2) has a total dissolved solids (TDS) concentration of less than 10,000 mg/L; and (3) is of a quality that can be used without treatment or that can be treated using methods reasonably employed by public water systems. It is important to note that even though groundwater at APG may technically be considered a potential drinking water source, the natural groundwater quality is generally poor. Groundwater of the area typically contains levels of iron, manganese, chloride, and TDS well in excess of Secondary Maximum Contaminant Levels (SMCLs) established to protect the aesthetic qualities of water, such as taste or staining of clothing and fixtures.

Once the quality of the aquifers was determined to be acceptable, the plausibility of using the groundwater for drinking water was evaluated, considering the location of the study area relative to off-site groundwater use areas, historical use of groundwater from the area, and the presence of existing water supply wells. Drinking water exposures were selected for evaluation at study areas where there is the potential for groundwater to migrate off-site and to contaminate existing drinking water sources (criterion 1); or where there has been historical use of groundwater and where water supply wells still exist (criterion 2).

Hypothetical future drinking water exposures were selected for evaluation at the Nike, Phillips Army Airfield, and Michaelsville Landfill study areas based on criterion 1 and at Carroll Island, Graces Quarters, and Canal Creek based on criterion 2. Where there is the potential for off-site migration and contamination of existing drinking water supplies, residential exposure scenarios were selected for evaluation. Where water supply wells currently exist, worker exposure scenarios were selected for evaluation.

Drinking water exposures were not selected for evaluation for O-Field and J-Field. For these study areas, there is no potential for groundwater to contaminate off-site drinking water supplies and no water supply wells currently exist. Given the institutional controls at APG, as well as the institutional knowledge of the contaminated nature of the groundwater at APG, it is extremely unlikely that new water supply wells would be constructed in known contaminated areas.

In all cases, justification is provided for any complete exposure pathways not evaluated in the risk assessment. Not all assessments of complete pathways performed for APG are quantitative. For example, in cases where a complete pathway exists (i.e., chemicals are known to be present in a medium that may be contacted by populations using that area), but the available data are not adequate to characterize the nature and extent of contamination, a qualitative assessment was performed.

4.3.1.2 Estimation of Exposure

In this step of the assessment, exposures (intakes) were quantified. In accordance with EPA (1989a) recommendations, intakes were derived to represent reasonable maximum exposures (RMEs). Intakes are typically determined in two stages; first, chemical concentrations are estimated at the potential exposure point (exposure point concentration), and then pathway-specific intakes are calculated.

4.3.1.2.1 Exposure Point Concentrations

Exposure point concentrations were based on environmental monitoring data alone or in combination with estimated values based on fate and transport modeling. In conformance with EPA (1989a) recommendations, the exposure point concentration used for the RME case should be the 95% upper confidence limit (UCL) on the arithmetic mean exposure concentration over time for each chemical. However, if the UCL on the mean exceeded the maximum detected concentration, the maximum concentration was selected as the RME concentration, as recommended by EPA (1989a). This situation can occur when the variance of the data is large and the sample size is small. Recent research by Clement (1990) indicates that applying EPA (1989a) procedures to groundwater may result in a major overestimate of risk. These procedures are used in this document to comply with EPA guidance. Their use should not be considered as validation of the procedure by Clement, ICF/KE or USATHAMA.

In this assessment, a statistical procedure developed by Land (Gilbert 1987, Land 1971, 1975) was used to estimate the 95% UCL on the arithmetic mean. This procedure assumes that the data are log-normally distributed. The choice of this procedure is supported by studies that show environmental contaminants to be log-normally distributed in nature (Dean 1981, Ott 1988). The equation for calculating the 95% UCL on the arithmetic mean is presented below (Land 1971, 1975):

$$UL_{(95th)} = EXP\ [AM + (0.5 \times STD) + ((VAR \times H_{(95th)}/(N - 1)^{1/2})] \qquad \text{(Eq. 1)}$$

where:

UL = 95% UCL on the arithmetic mean;

EXP = the anti-natural log of the sum of the parameters within the brackets;

AM = the arithmetic mean of the natural log transformed data;

STD = the standard deviation of the natural log transformed data;

VAR = the variance of the natural log transformed data;

H = tabular value, based on degrees of freedom and variance of the data for the 95th percentile of the H distribution (Land 1971, 1975); and

N = sample size.

In some cases, not enough samples (i.e., fewer than three) were available to calculate the 95% UCL on the arithmetic mean. In these cases, the maximum detected concentration of the chemical was used as the exposure concentration for the RME case.

To calculate the arithmetic mean and 95% UCL on the arithmetic mean, nondetects were included by using one-half of each sample-specific detection limit, in the same manner as discussed in Section 4.2, with the same check for high detection limits being applied.

4.3.1.2.2 Intakes

Before intakes for a specific population are calculated, it is necessary to determine what types of exposures (i.e., long-term or acute) may be important. Long-term exposure to relatively low chemical concentrations are generally of most concern at hazardous waste sites. Long-term exposures can be either chronic (more than 7 years exposure; EPA 1989a) or subchronic (14 days to 7 years exposure; EPA 1989a). In some situations at APG, however, acute exposures that take place as a single event or over a day could be of concern. Considerations that determine whether an acute exposure should be evaluated include the toxicological or other acute hazard characteristics of the chemical, the occurrence of high concentrations of a chemical, and the potential for a large release or other acute episode such as an explosion, as well as the expected exposure duration for the population of concern. Acute exposures are evaluated either qualitatively or quantitatively in this risk assessment, depending upon the data available to support such evaluations.

Exposures are quantified by calculating chemical intakes.[2] Intakes calculated for chronic exposures are termed chronic daily intakes (CDIs), and those for subchronic exposures are termed subchronic daily intakes (SDIs). Acute exposures are generally quantified in terms of a single dose or an exposure concentration (e.g., mg/m^3 in air) associated with a particular effect. Intakes are typically expressed as the amount of a substance taken into the body per unit body weight (bw) per day, i.e., mg/kg-day. Intakes are averaged over a lifetime for carcinogens and over the exposure period for noncarcinogens (EPA 1989a). This difference in averaging time relates to the currently held scientific opinion that the mechanism of action for carcinogenic and noncarcinogenic toxicants are different (discussed further in Section 4.3.2 below).

Three categories of variables are used to calculate intakes (EPA 1989a):

- Chemical-related variables (exposure point concentration);
- Variables that describe the exposed population (contact rate, exposure frequency and duration, and body weight); and
- Assessment-determined variable (averaging time).

To calculate the RME intake, the RME concentration for each chemical is combined with reasonable maximum values for the other exposure parameters listed above. For this assessment, values for these parameters were selected based on site-specific information or values provided in EPA guidance (EPA 1989a).

A generic equation for calculating intakes is shown below.

$$I = \frac{(C)(CR)(EF)(ED)}{(BW)(DY)(YL)} \qquad \text{(Eq. 2)}$$

where:

I = intake (the amount of chemical at the exchange boundary [mg/kg bw-day]),

C = exposure concentration (the average concentration contacted over the exposure period [e.g., in mg/L for aqueous solutions]),

CR = contact rate (the amount of contaminated medium contacted per unit time or event [e.g., L/day]),

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[2] Intakes are exposures normalized for time and body weight and are expressed as mg of chemica/kg of body weight-day.

EF = exposure frequency (days/year),

ED = exposure duration (years),

BW = average body weight (average over exposure period [kg]),

DY = days/year (365 days/year), and

YL = period over which risk is being estimated (i.e., a lifetime of 70 years for carcinogens, or the duration of exposure [ED] for noncarcinogens) (years).

Intake, as defined above, is expressed as the amount of chemical at the exchange boundary (e.g., skin, lung, gut) available for absorption and is therefore not equivalent to absorbed dose, which is the amount of chemical absorbed into the blood stream. For dermal exposures with soil or water, however, absorbed doses are calculated incorporating factors that reflect the percentage of the chemical that moves across the skin. The equations for estimating human intakes for each exposure route evaluated are provided in each individual risk assessment.

4.3.2 HUMAN TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for the chemicals of concern to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a chemical and the increased likelihood and/or severity of adverse effects. Toxicity assessments are generally conducted in two stages: hazard assessment and dose-response evaluation. Hazard assessment is the process of determining whether exposure to a chemical can cause an increase in the incidence or severity of a particular adverse health effect and whether the adverse health effect is likely to occur in humans. Dose-response evaluation is the process of quantitatively evaluating the relationship between the dose of the chemical received and the incidence of adverse health effects in the exposed population. For this report, the results of the hazard assessment and dose-response evaluation for each chemical of potential concern are summarized in the toxicity profiles presented in Appendix B.

The results of the toxicity assessment are also summarized in the risk assessment for each study area in a table of toxicity criteria for evaluating carcinogenic and noncarcinogenic health effects. It should be noted that toxicity criteria are not available for all chemicals of potential concern selected for assessment for each of the study areas. These chemicals are identified in each risk assessment, and the consequences of excluding them from the risk assessment are discussed in the risk characterization section of the risk assessments.

Toxicity criteria are provided for noncarcinogenic effects and for carcinogenic effects, the two categories of chemical toxicity into which pollutants are separated for risk assessment purposes. This distinction relates to the currently held scientific opinion that the mechanism of action for each category is different. For the purpose of assessing risks associated with potential carcinogens, EPA (1986a) has adopted the scientific position that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is described as a no-threshold mechanism, since there is essentially no level of exposure (i.e., a threshold) to a carcinogen that will not result in some finite possibility of causing the disease. In the case of chemicals exhibiting noncarcinogenic effects, however, EPA has adopted the position that organisms have protective mechanisms that must be overcome before the toxic endpoint is manifested. For example, if a large number of cells performs the same or similar functions, it would be necessary for significant damage or depletion of these cells to occur before an effect could be seen. This threshold view holds that a range of exposures up to some finite value can be tolerated by the organism without appreciable risk of causing adverse effects.

4.3.2.1 Health Effects Criteria for Potential Carcinogens

Slope factors, developed by EPA's Health Assessment Group (HAG) for potentially carcinogenic chemicals and expressed in units of $(mg/kg\text{-}day)^{-1}$, are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies must usually be conducted using relatively high doses in order to detect possible adverse effects. Because humans are expected to be exposed at lower doses than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response curve. The 95% upper confidence limit slope of the dose-response curve is subjected to various adjustments, and an interspecies scaling factor is applied to derive the slope factor for humans. Thus, the actual risks associated with exposure to a potential carcinogen that have been quantitatively evaluated based on animal data are not likely to exceed the risks estimated using these slope factors, but they may be much lower. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an *ad hoc* basis. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. Slope factors based on human epidemiological data are also derived using conservative assumptions, and they too are unlikely to underestimate risks. Therefore, while the actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a slope factor, they could be considerably lower.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer. Groups B1 and B2 chemicals (probable human carcinogens) are agents for which there is limited (B1) or inadequate (B2) evidence of carcinogenicity from human studies but for which there is sufficient evidence of carcinogenicity from animal studies. Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available. Group E chemicals (evidence of noncarcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

4.3.2.2 Health Effects Criteria for Noncarcinogens

Health criteria for chemicals exhibiting noncarcinogenic effects are generally developed using reference doses (RfDs) developed by the EPA RfD Work Group or RfDs obtained from Health Effects Assessments (HEAs). An RfD is an estimate of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs, usually derived either from human studies involving work-place exposures or from animal studies, are adjusted using uncertainty factors. An RfD provides a benchmark to which chemical intakes may be compared. EPA has developed chronic and subchronic RfDs, both expressed in units of mg/kg-day. EPA (1989a) recommends that chronic RfDs be used to evaluate exposures of 7 years to a lifetime in duration and subchronic RfDs be used to evaluate exposures of 2 weeks to 7 years in duration.

4.3.3 HUMAN RISK CHARACTERIZATION

In this final step of the risk assessment process, the exposure and toxicity information are integrated to develop both quantitative and qualitative estimates of risk. Noncarcinogenic effects are quantitatively characterized by comparing estimated intakes of substances with RfDs. To characterize potential carcinogenic effects, the incremental probability that an individual will develop cancer over a lifetime of exposure is estimated using projected intakes of chemicals and chemical-specific dose-response information (the cancer slope factor).

An important aspect of the risk characterization process is to ensure that the assumptions used in the exposure estimates are compatible with the assumptions used in developing the toxicity values. For example, because slope factors are based on average lifetime exposure, exposure duration must be expressed in those terms. In addition, for estimating potential noncarcinogenic effects, exposures 2 weeks to 7 years in duration should be compared to subchronic RfDs and those greater than seven years to chronic RfDs. In the absence of a subchronic RfD, in accordance with EPA guidance (EPA 1989a), the chronic RfD may be used.

4.3.3.1 Carcinogenic Risks

As noted above, carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. This approach is consistent with EPA's guidance on carcinogen risk assessment (EPA 1986a). Excess lifetime cancer risks are obtained by multiplying the chronic daily intake (CDI) of the contaminant under consideration by its cancer slope factor:

$$\text{Excess upperbound lifetime cancer risk} = \text{CDI} \times \text{SF} \qquad \text{(Eq. 3)}$$

where

CDI = chronic daily intake of the chemical (mg/kg-day), and

SF = cancer slope factor for the chemical $(\text{mg/kg-day})^{-1}$.

According to EPA guidance (EPA 1989a), this is appropriate for cancer risks of less than 10^{-2} (i.e., probability of less than 1 in 100 of contracting cancer). When risk is greater than 10^{-2}, the linear approach described above is not valid, and risk is calculated by the following equation:

$$\text{Excess upper-bound lifetime cancer risk} = 1\text{-exp}(-\text{CDI} \times \text{SF}) \qquad \text{(Eq. 4)}$$

A risk level of 10^{-6} represents the probability of 1 in 1 million that a person will contract cancer from exposure to a potential carcinogen at a given concentration. This risk level (10^{-6}) is often used by regulatory agencies as a benchmark for determining the need for corrective action at hazardous waste sites.

In the absence of specific information on the toxicity of a mixture of potential carcinogens, EPA (1986c) recommends that the estimates of risk for each carcinogen be summed to obtain the total excess upperbound lifetime cancer risk associated with the exposure being evaluated.

4.3.3.2 Noncarcinogenic Hazards

Unlike carcinogenic effects, noncarcinogenic effects are not expressed as incidence probabilities. The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period with an RfD derived for a similar exposure period. This ratio is called a hazard quotient. (The particular methods used to quantify acute exposures are discussed in the individual risk assessment for each of the eight study areas.)

In general, if the hazard quotient is less than 1 (i.e., if the daily intake is below the designated EPA health criterion), the chemical is considered unlikely to be associated with any adverse noncarcinogenic health effects.

In the absence of specific information on the toxicity of the mixture of chemicals to be assessed or on similar mixtures, EPA (1986c) guidelines recommend assuming that the effects of different components of the mixture are additive when affecting a particular organ or organ system. As a first approximation of this for noncarcinogenic hazard, the hazard quotients for each individual chemical within each scenario are summed to produce a Hazard Index (HI):

$$HI = \Sigma \frac{DI_i}{RfD_i} \qquad \text{(Eq. 5)}$$

where

HI = Hazard Index;

DI_i = daily intake [chronic or subchronic] for chemical i (mg/kg-day); and

RfD_i = reference dose for chemical i (mg/kg-day).

If the Hazard Index is less than 1, the combined intake of chemicals by the exposure route under consideration is unlikely to pose a health risk. If the Hazard Index exceeds 1, the chemicals are subdivided according to their toxicological effects (critical endpoints or target organs), and the risk for each endpoint is considered separately (EPA 1986c).

4.3.3.3 Adjustment of Toxicity Values

Toxicity criteria used in risk characterization must be consistent with the route of exposure being evaluated. For example, a toxicity value based on localized lung tumors resulting from inhalation exposure might not be appropriate for evaluating oral or dermal exposures. Currently, the only route-to-route extrapolation that EPA considers appropriate is the extrapolation of dermal toxicity values from values derived for oral exposure (EPA 1989a). In evaluating dermal exposures, because the intake estimated in the exposure assessment is the amount of the substance absorbed per kg of body weight per day, it may be necessary to derive a toxicity value based on absorbed dose from a toxicity value based on administered dose. Such an adjustment may also be necessary for other routes of exposure when the toxicity value is expressed as an absorbed dose. It is also necessary to make adjustments when the exposure medium is different for the toxicity study and the exposure situation of concern, e.g., a toxicity study dose administered in water and an exposure situation involving ingestion of contaminated soil.

4.4 ECOLOGICAL ASSESSMENT

The approach used to assess potential ecological impacts is conceptually similar to that used to assess human health risks; potentially exposed populations (receptors) are identified, and then information on exposure and toxicity is combined to derive estimates of risk. The scope of ecological assessments is generally different from human health assessments, however, in that ecological assessments typically focus on potential impacts in a population of organisms rather than on the individual organism (as in human health assessments). In addition, because natural systems are composed of a variety species, ecological assessments evaluate potential impacts in numerous species instead of a single species (as in human health assessments).

Ideally, ecological assessments should evaluate risks to communities and ecosystems, as well as to individual populations. However, because of the large number of species and communities present in natural systems, such ecosystem-wide assessments are very complex, and appropriate assessment methodologies have not yet been developed. In addition, dose-response data on community or ecosystem responses are generally lacking. Consequently, quantitative environmental assessments in this report are limited to the population level. Evaluations of potential impacts to communities or ecosystems are qualitative.

The ecological assessments in this report evaluate potential impacts associated with each individual study area. Potential cumulative impacts to the upper Chesapeake Bay region surrounding APG from all eight study areas together are discussed in Chapter 13. However, the degree to which potential impacts can be characterized is highly dependent upon the data available to support such estimates. For potential impacts to be estimated quantitatively, extensive data are required, including: information regarding contaminant release, transport, and fate; characteristics of potential receptor populations (e.g., seasonal dynamics of anadromous fish, population dynamics of terrestrial wildlife, food preferences of key ecological receptors); and adequate supporting toxicity data for the principal chemicals of concern. The degree to which the available data can fulfill these and other data requirements dictates the extent to which potential ecological impacts are evaluated for each of the eight study areas.

The approaches and methods used to evaluate ecological risks in this report are described below for each of the principal components of the assessment process: receptor characterization, exposure assessment, toxicity assessment, and risk characterization. It is emphasized that the ecological assessments conducted in this report are predictive risk assessments. Comprehensive field studies of ecological impacts have not yet been conducted at the eight study areas being evaluated. The results of the ecological assessments conducted in this report will be useful in focusing future field studies on the media and/or study areas where the potential for ecological impact is the greatest.

4.4.1 RECEPTOR CHARACTERIZATION

The first step in the ecological assessment process was to characterize the plant and wildlife species and habitats that occur in the study area and to select receptor populations for evaluation. The eight study areas at APG provide a diversity of habitats that support a wide variety of plant and animal species. Because of this diversity, it is not feasible to assess impacts on every species potentially affected at a particular study area. A common approach to this problem in ecological assessments is to select "indicator" species for detailed evaluation and to assume that impacts on these species are representative of potential impacts in other species present at the site, or alternatively, are representative of potential maximum impacts associated with the site. The selection of indicator species is driven by several factors, including the potential for exposure (e.g., based on habitat preferences), the sensitivity (e.g., endangered species) or susceptibility (e.g., based on foraging strategies) to chemical exposures, the availability of chemical data for potential exposure media, ecological significance (e.g., role of species in the community or in predator-prey relationships) and societal value (e.g., commercially important fish species). The "indicator species" approach was used in this assessment to select receptor populations for evaluation.

Based on the considerations outlined above and the habitat characteristics of the eight study areas being evaluated, the following species or species groups were selected for consideration as indicator organisms for each of the study areas.

Terrestrial Species

- Birds - great blue heron, mallard duck, spotted sandpiper, bald eagle, peregrine falcon
- Mammals - white-tailed deer, muskrat, raccoon

Aquatic Species

- Fish - herring, temperate bass, catfish, killifish, sunfish
- Amphibians - green frog (principally larvae)
- Invertebrates - copepods/water fleas, aquatic insects, benthic invertebrates
- Plants - Phytoplankton, aquatic macrophytes

The rationale for the selection of each of these species or species groups is presented in Tables 4-6 and 4-7 for terrestrial and aquatic species, respectively. All endangered species found at APG were included on the list of potential receptor species. The group of selected receptor species does not include terrestrial plants and soil-dwelling species because very few surface soil data are available for the eight study areas being investigated. Carnivorous mammals (e.g., mink) were not included because they are not common in the eight study areas being investigated. Reptiles were excluded because few toxicity data are available to evaluate potential impacts in this group of organisms. The particular indicator species or species groups selected for evaluation at each study area depend upon the specific habitat characteristics of the area, as well as the nature and extent of contamination. The rationale for the selection of indicator species for a particular study area is described in the text of each assessment. Appendix D provides detailed species profiles for the vertebrate indicator species. Such profiles are not provided for the invertebrate or plant receptors because of the large diversity of species in these broadly defined receptor groups.

4.4.2 EXPOSURE ASSESSMENT

After the potential receptors were determined, the pathways by which they might be exposed to chemicals of potential concern were identified. The sources, releases, types, and locations of the chemicals in each study area, the likely environmental fate and transport of the chemicals, and the location and activity of receptor populations were considered in identifying the exposure pathways.

Terrestrial wildlife may be exposed to chemicals of potential concern in surface soil, surface water, and sediment by several pathways: (1) ingestion of soil or sediment while foraging or grooming; (2) ingestion of food (plant or animal) that has accumulated chemicals from soil, surface water, or sediment; (3) ingestion of surface water; and (4) dermal absorption. This assessment focused on evaluation of potential exposures via ingestion of food and ingestion of surface water. Exposures via

TABLE 4-6

RATIONALE FOR SELECTION OF PARTICULAR SPECIES AS INDICATOR SPECIES FOR APG ECOLOGICAL ASSESSMENTS: TERRESTRIAL SPECIES

Taxonomic Group/Species	Probable Occurrence and Abundance at APG	Foraging Guild	Reasons for Selection
BIRDS			
Great blue heron (Ardea herodias)	Common in the marshes and shoreline habitats of APG	Piscivore/aquatic carnivore; feeds almost exclusively on fish and frogs	Widespread occurrence at APG; susceptible to exposures via ingestion of aquatic life that has accumulated contaminants from surface water and sediment
Mallard duck (Anas platyrhynchos)	One of the principal dabbling ducks wintering at APG; inhabits ponds, creeks, rivers and marshes at APG	Principally an aquatic herbivore; some animal matter in diet	Widespread occurrence at APG; regional value as a recreational species
Spotted sandpiper (Actitis macularia)	Likely to occur in marshes and shoreline habitats at APG	Aquatic insectivore; sediment-dwelling invertebrates also in diet	Susceptible to exposures to sediment contaminants via ingestion of benthic organisms
Bald eagle (Haliaeetus leucocephalus)	Uses APG as a foraging, breeding and roosting area	Carnivore/piscivore	Endangered species; APG provides over-winter habitat for an estimated 17% of the wintering bald eagles in the Northern Chesapeake Bay (Millsap et al. 1983)
Peregrine falcon (Falco peregrinus)	Over-winters at APG	Carnivore	Endangered species
MAMMALS			
White-tailed deer (Odocoileus virginianus)	Abundant and widespread in a variety of habitats	Herbivore	Abundance at APG; recreational value
Muskrat (Ondatra zibethicus)	Probably abundant in marshes and marsh/creek systems	Aquatic herbivore	Potential for exposure to surface water and sediment contaminants given its habitat requirements
Raccoon (Procyon lotor)	Possibly common at APG along streams in wooded areas	Omnivore	Susceptible to exposures via ingestion of aquatic life that has accumulated chemicals from surface waters and/or sediments

TABLE 4-7

RATIONALE FOR SELECTION OF PARTICULAR SPECIES GROUPS FOR APG ECOLOGICAL ASSESSMENTS: AQUATIC SPECIES

Taxonomic Group/Selected Species Groups	Probable Occurence and Abundance at APG	Representative Species Within Group	Reasons for Selection
FISH			
Herrings (Clupeidae)	Members of this family are widespread in various habitats at APG; primarily spawning and nursery species at APG	Alewife (Alosa pseudoharengus), blueblack herring (A. aestivalis), American shad (A. sapidissima), Atlantic menhaden (Brevoortia tyrannus), bay anchovy (Anchoa mitchilli)	Menhaden, shad and herring are commercially important species; shad populations have collapsed in the Chesapeake Bay; bay anchovy is an important component of the food web of many sport and commercial fishes
Temperate basses (Percichthyidae)	APG is a spawning and nursery ground for members of this family	White perch (Morone americana), stripped bass (M. saxatilis)	Commercially important fish
Catfish (Ictaluridae)	Members of this resident species are widespread; most likely to inhabit larger water bodies	Channel catfish (Ictalurus punctatus)	Commercially important fish
Killifishes (Cyprinodontidae)	Probably ubiquitous in marsh, creek, and tidal flat habitats	Mummichog (Fundulus heteroclitus)	Abundance at APG
Sunfishes (Centrarchidae)	Common in freshwater creeks and ponds	Bluegill (Lepomis macrochirus)	Abundance at APG
AMPHIBIANS			
Frogs	Probably abundant at APG; optimal habitat includes springs, marshes, and pond or lake edges	Green frog (Rana clamitans)	Probably abundant at APG; potential for exposure to surface water and sediment contaminants (of particular concern for larvae, i.e., tadpoles)
INVERTEBRATES			
Copepods/water fleas	Copepods are abundant in all waters of Chesapeake Bay estuarine system; water fleas occur in both fresh water and estuarine habitats	Acartia spp. (a copepod), Podon polyphemoides (a waterflea), Daphnia spp. (a waterflea)	Important component in the estuarine food chain
Aquatic insects/insect larvae	Abundant in all freshwater habitats at APG	Chironomids	Important component of aquatic and terrestrial food chains
Benthic invertebrates	Associated with sediments of freshwater and estuarine waters	Isopods, polychaete worms, clams	Important component of aquatic food chain
PLANTS			
Phytoplankton	Abundant in all surface water habitats	Diatoms, blue-green algae, dinoflagellates	Base of aquatic food chain
Macrophytes	Abundant in many near-shore habitats at APG	Widgeon grass (Ruppia maritima), wild celery (Vallisneria americana), cattail (Typha sp.)	Provide food and cover for numerous species of aquatic and terrestrial wildlife

ingestion of soil or sediment while foraging or grooming and dermal absorption were not evaluated because few data are available to assess wildlife exposures via these pathways. Terrestrial wildlife could also be exposed via inhalation to airborne chemicals, but inhalation exposures were not evaluated in this assessment because few data are available to support wildlife exposure and toxicity assessments for chemicals in air.

Aquatic life may be exposed to chemicals of potential concern by respiration, direct contact with water and sediment, and ingestion of water (e.g., in filter feeders), sediments, and food containing chemicals of potential concern. However, most available aquatic toxicity data express toxicity as a function of concentration in the exposure medium (i.e., surface water or sediment concentration). To be consistent with available toxicity data, exposures to aquatic life were evaluated in this assessment by using measured or estimated surface water and sediment concentrations.

Not all potentially complete exposure pathways nor all chemicals were selected for evaluation. A qualitative screening was conducted on all potential exposure pathways and chemicals to identify the pathways and chemicals considered most important for characterizing the potential ecological impacts associated with a study area. Only those pathways and chemicals that are likely to contribute significantly to risk were evaluated further in the assessment. The rationale for the selection of pathways for evaluation is provided in the text for each of the study areas. Selected exposure pathways were evaluated either quantitatively or qualitatively depending upon the availability and quality of data to support quantitative exposure estimates.

For each exposure pathway selected for quantitative evaluation, concentrations at the exposure point were estimated, and then the receptor-specific exposures were quantified. Exposure point concentrations were estimated using environmental monitoring data either alone (if available and regarded as adequate for evaluating exposures) or in conjunction with environmental fate and transport models. If monitoring data were used, the exposure concentration is the 95% upper confidence limit on the mean or the maximum concentration (whichever is smaller), as discussed in Section 4.3.1.1. Bioconcentration factors (BCFs) may be used to characterize chemical accumulation in aquatic species consumed by terrestrial wildlife receptors. Bioconcentration factors provide a measure of the extent of chemical partitioning at equilibrium between a biological medium such as fish tissue or plant tissue and an external medium such as water. However, such exposures were evaluated only for those chemicals with BCFs greater than 300, focusing the assessment on those chemicals potentially associated with the greatest ecological impact. This approach is consistent with EPA's (1989b) statement that BCFs greater than 300 are generally considered significant for aquatic species.

Following estimation of exposure point concentrations, exposures were quantified for each exposure pathway/receptor combination selected for quantitative evaluation. For terrestrial wildlife, exposure was quantified by estimating the daily dose in mg/kg body weight for the selected receptor species. Factors such as habitat, food preference, and home range as described in the available literature were used to estimate exposure. For aquatic species, measured or estimated chemical concentrations in surface water and sediment were used for exposure estimates. Total concentrations were used as exposure concentrations for surface water.

4.4.3 TOXICITY ASSESSMENT

In the toxicity assessment, the chemicals of potential concern were characterized with respect to their terrestrial and aquatic toxicity. Relevant toxicity data were summarized for the selected indicator species or species groups, and toxicity criteria to be used in the assessment of impacts were derived. The procedures used to generate toxicity criteria for terrestrial and aquatic species are summarized below.

4.4.3.1 Terrestrial Toxicity

For terrestrial wildlife, chronic toxicity criteria conceptually similar to human health RfDs were developed. Published toxicity studies were reviewed to identify dose-response information for the chemicals of potential concern. Toxicity studies conducted on the selected indicator species or closely-related species (defined here as within the same genus, family, or order) were preferentially used to develop toxicity criteria for the APG assessments under the assumption that lesser evolutionary distance implies greater morphological and physiological similarity, which in turn implies greater similarity in response to toxic substances. This relationship has been shown for aquatic species (Suter et al. 1985), but the available data on terrestrial wildlife toxicity do not definitively support nor refute such an assumption. The assumption was made here and regarded as reasonable in the absence of additional information that defines more precisely the relationship between taxonomic similarity and toxicant sensitivity.

To the extent possible, toxicity criteria were derived from studies that evaluated effects on reproduction, development, or survival, as these endpoints have direct relevance to evaluation of potential population-level impacts. Less relevant endpoints (e.g., enzyme effects, organ lesions) generally were used only in the absence of more appropriate data or if they could be directly linked to reproduction, development, or survival. For example, reductions in acetylcholinesterase (AChE) activity can be linked directly to survival and would therefore be considered an appropriate endpoint for these assessments. Data from subchronic studies (less than 90 days for terrestrial species) were used in the absence of chronic studies.

The toxicity criteria that were developed are estimates of the dose at which no adverse effects are likely to occur in the selected indicator species. Toxicity criteria are based on no-observed-adverse-effect levels (NOAELs) reported for the selected indicator species or closely related species (i.e., same taxonomic order), if available.

If a NOAEL was not available, a lowest-observed-adverse-effect level (LOAEL) was used as the basis for the toxicity value. A factor of 10 (divisor) was applied to the LOAEL to estimate a NOAEL. This factor is an arbitrary value used to reflect the uncertainty in the estimates of the "safe" dose. Information that would permit more precise effect-to-no-effect extrapolations was not available for terrestrial wildlife species. A similar factor was applied in the derivation of human health RfDs, and is regarded here as similarly appropriate for the protection of wildlife species.

If no toxicity data were available for the selected indicator species or closely related species, NOAELs or LOAELs reported for other terrestrial species were used to estimate toxicity in the selected indicator species. A factor of 10 (divisor) is applied to the selected NOAEL or LOAEL to account for interspecies variability in sensitivity if the NOAEL or LOAEL was derived from a toxicity database containing information on only one or two species within a given class (i.e., birds or mammals). If toxicity information was available for three or more species within a given class, no uncertainty factor was applied, under the assumption that the available toxicity data adequately represent the range of sensitivities exhibited by wildlife species of that class. A similar approach for evaluating wildlife toxicity was used by Newell et al. (1987) in developing residue criteria for the protection of piscivorous wildlife for the State of New York.

If no information was available on chronic or subchonic toxicity, acute toxicity data were used to characterize potential wildlife toxicity. Median lethal dosages (LD_{50}s) are the acute toxicity values used. Again, toxicity values from studies on the selected receptor species or taxonomically similar species are used to develop toxicity criteria if available. In the absence of information from appropriate species, the lowest LD_{50} reported for other species was divided by a factor of 5 to derive the acute toxicity criteria for this assessment (birds and mammals treated separately). In evaluating the potential effects of pesticides on wildlife, EPA analyzed a subset of available dose-response data and suggested that if the estimated dose is less than one-fifth of the LD_{50} reported for a test species, no acute hazard can be presumed for any nonendangered wildlife species (Urban and Cook 1986). Although a similar relationship has not been investigated for other (nonpesticide) chemical groups, this rule was adopted for this risk assessment in the absence of more specific information regarding acute effect-to-no-effect extrapolations for other chemical groups. Under the proposed approach, no additional extrapolation was needed to account for interspecies variation.

4.4.3.2 Aquatic Toxicity

Toxicity for both surface water and sediment exposures was evaluated. (Toxicity values for aquatic life were not developed for specific receptor species. They were developed instead to be protective of the aquatic community as a whole by protecting most species [95%].) This is consistent with EPA regulatory approaches for protection of surface water quality.

4.4.3.2.1 Surface Water Exposures

For aquatic species, federal ambient water quality criteria (AWQC) were used to assess potential impacts. AWQC were derived to prevent unacceptable toxic effects for 95% of all families of aquatic vertebrates (fish [and amphibians for some chemicals]), invertebrates, and plants (Stephen et al. 1985, EPA 1986f), and therefore were regarded in this assessment as sufficiently protective of all families of species at APG. The only case in which an AWQC was not used to evaluate potential impacts on aquatic life is when it was developed to protect a terrestrial receptor more sensitive than aquatic life (e.g., the mercury AWQC to protect humans, the PCB AWQC to protect piscivorous wildlife). In these cases, toxicity values were derived for the protection of aquatic life, as described below.

Both acute and chronic AWQC were used in this assessment. AWQC have been developed for fresh water and salt water environments, but not specifically for estuarine environments like those at APG. If both fresh water and salt water AWQC values were available for a particular chemical of concern, the lower of the two values was used to evaluate potential impacts on aquatic life. This approach is consistent with EPA (1989e) guidance. For hardness-dependent criteria, salt water criteria were used if the hardness of the surface water being evaluated was greater than 400 mg $CaCO_3$/L. This is because the equations relating toxicity to hardness generally are not valid for hardness above this value.[3]

For chemicals for which no AWQC have been developed, a literature review was conducted to obtain fish, invertebrate, and plant aquatic toxicity data for the chemicals of concern. 96-Hour or 48-hour median lethal concentrations (LC_{50}s) are used as acute values; no-observed-effect concentrations (NOECs) or lowest-observed-effect concentrations (LOECs), maximum-acceptable-toxicant concentrations (MATCs), or longer-term LC_{50}s were used as chronic values.

Acute and chronic aquatic toxicity criteria were developed by selecting the lowest of the acute and chronic toxicity values reported in the literature for fish, invertebrates, and plants. An uncertainty factor of 10 was applied to the lowest acute and chronic values to derive the toxicity criteria for this assessment if toxicity data were available on four or fewer genera. This approach is similar to that

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[3] Stephan, C. 1990. Personal communication, EPA ERL, Duluth. April 1990.

used by EPA (1987) to derive water quality advisories.[4] The number derived using this approach is conceptually similar to AWQC and is meant to provide a concentration level that is protective of the majority of aquatic species across all receptor groups (i.e., fish, invertebrates, and plants).

If no chronic toxicity data were available for a given chemical, chronic toxicity values were derived by dividing the lowest LC_{50} by an acute-to-chronic ratio (ACR) that also takes into account interspecies differences in sensitivity. Kenaga (1982) evaluated available acute and chronic toxicity data for fish and aquatic invertebrates to derive an empirical relationship between acute LC_{50} values and chronic MATCs. He found that the ACRs for most chemicals for fish and *Daphnia* (an invertebrate) are not very different and that the ACRs for most chemicals are within one order-of-magnitude across species. He calculated ACRs for specific chemical classes and concluded that approximately 86% of all chemicals examined (84 total) have ACR values below 100 for all species. He found that high ACR values (>125) were generally associated with pesticides and inorganic chemicals and were probably due to specific mechanisms of action unique to these chemicals. He also found that industrial organic chemicals such as halogenated aliphatics, which exhibit narcotic effects, do not produce large ACRs. ACRs of 25 or less appear to be appropriate for predicting chronic toxicity from acute toxicity for these chemicals. These results were supported by the work of Call et al. (1985).

Based on the results of Kenaga (1982) and Call et al. (1985) an ACR of 25 was used for low molecular weight non-ionizable ("neutral") organic chemicals, and an ACR of 100 was used for all other chemicals. This approach may overestimate MATCs (i.e., may predict an MATC that is actually an effect level) for chemicals with unique mechanisms of action (e.g., metals, pesticides). However, this approach is used to estimate toxicity in the absence of appropriate toxicity data for these chemicals. It should be noted that most metals potentially of concern at the APG study areas have established AWQC. Therefore, estimates of chronic toxicity using the above approach were not necessary, eliminating some of the uncertainty associated with this approach. As stated above, the ACRs derived using this approach account for interspecies variation. Therefore, additional interspecies extrapolations were not required.

4.4.3.2.2 Sediment Exposures

Standards similar to AWQC have not been developed for sediment contaminants. Several approaches have been proposed for developing sediment criteria including the sediment triad approach (Chapman 1986), the screening-level concentration approach (Neff et al. 1987 in Chapman et al. 1987), the apparent effects threshold approach (Chapman et al. 1987), and the equilibrium partitioning approach (EPA 1988b, Shea 1988). Specific criteria have not yet been officially proposed by EPA. In the absence of specific sediment criteria, sediment toxicity values were derived from the results of laboratory and/or field studies. Acute and chronic toxicity were evaluated to the extent that data were available. No methods have been proposed for acute-to-chronic extrapolations for sediment data, so these types of extrapolations were not conducted in these assessments.

Because limited information is available on site-specific sediment chemistry, no extrapolations were made on literature-derived values to correct for differences between laboratory sediment conditions and those that may exist at the site. However, sediment characteristics such as f_{oc}, pH, redox potential, and acid-soluble sulfides can have a strong influence on the bioavailability and toxicity of chemicals in sediment.

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[4] Water quality advisories are derived for chemicals for which insufficient data are available to derive AWQC.

4.4.4 RISK CHARACTERIZATION

Potential ecological impacts were characterized by comparing estimated exposures with appropriate toxicity values. Exposures that exceed the selected toxicity values suggest that individual and population-level impacts may be possible in the selected receptor species. Additivity of toxic effects was evaluated for chemical groups that have similar mechanisms of action (e.g., non-ionizable organic chemicals, phenols, PAHs). Other types of chemical interactions (i.e., synergism, antagonism) were not considered because of the limited data available to evaluate such interactions. As discussed previously, quantitative evaluations of impacts were limited to the population level. The implications of population-level impacts on community structure and function are discussed qualitatively.

4.5 UNCERTAINTIES IN THE RISK ASSESSMENT

In this section, the principal sources of uncertainty surrounding the estimates of human health and environmental impact at APG are discussed. As in any risk assessment, the estimates of risks associated with the APG study areas are not fully probabilistic (as noted by EPA 1989a). Rather, these estimates are conditional based on a number of assumptions regarding exposure conditions and toxicity and are often defined by risk management considerations. As a result, an evaluation of the uncertainties associated with these assumptions is critical to placing the risk estimates in the proper perspective. In addition, an evaluation of the uncertainties also facilitates the identification of areas where additional data gathering can significantly improve estimates of risk and therefore the selection of remedial alternatives.

There are uncertainties associated with each step of the risk assessment, but in practice the four areas that are associated with the largest amount of uncertainty are:

- The selection of chemicals to be evaluated quantitatively in the risk assessment;
- The analytical data used in the risk assessment;
- The fate and transport models and assumptions used to assess human and ecological exposures; and
- Toxicity values, both with respect to availability of these values and the sources of uncertainty associated with the available toxicity values.

Other uncertainties are associated with the choice of exposure pathways to be evaluated in the risk assessments, and the intake parameters (other than concentration) used to assess exposure.

These uncertainties are common to all risk assessments to a greater or lesser extent and are discussed with respect to APG in general below. Particularly relevant sources of uncertainty associated with each study area are discussed in more detail in the appropriate section of the risk assessment for each study area.

4.5.1 UNCERTAINTIES RELATED TO THE SELECTION OF CHEMICALS FOR QUANTITATIVE EVALUATION

There are several reasons for the uncertainties associated with the selection of chemicals to be evaluated quantitatively in the risk assessments for the eight APG study areas. One important factor is the limitations of the monitoring studies on which these risk assessments were based. Because many of the monitoring studies were focused hydrogeologic investigations, they did not necessarily provide information on the full extent of chemical contamination in all media at a particular study area. In other cases, although the original study plan included a more comprehensive approach for contaminant characterization, the sampling could not be conducted for health and safety reasons. As a result, few study areas have adequate information on the nature or extent of surface soil contamination, or contamination in surface water and sediment environments. Consequently, risks associated with exposure to chemicals in these media could not be evaluated or could not be evaluated fully.

In some cases, certain chemicals were excluded from quantitative risk evaluations, because they were not specifically included in the chemical analyses selected for a particular medium. In these situations, it was necessary to rely on information regarding disposal history, chemical fate and transport, as well as any available sampling data, to predict whether a particular chemical could be present in a given medium. Quantitative evaluation in such situations is generally not possible, and these chemicals were selected for qualitative evaluation only.

4.5.2 UNCERTAINTIES ASSOCIATED WITH ANALYTICAL DATA

Uncertainties associated with the analytical data also contribute to the overall uncertainties surrounding the risk estimates for the individual APG study areas. These uncertainties can stem from several sources, including errors inherent in analytical methods or the characteristics of the matrix being sampled. Procedural or systematic error can be minimized by subjecting the data to a strict laboratory quality assurance/quality control review (QA/QC) and data validation process. It was assumed that the data obtained from the USATHAMA database (IRDMS) had received a thorough QA/QC review and validation. However, it is not known in all cases if the data obtained directly from study reports underwent any type of QA/QC review or data validation. Therefore, based on QA/QC concerns, there is a greater degree of uncertainty associated with the use of data from study reports, if the data have not been quality assured.

There is also some uncertainty associated with data obtained from IRDMS, primarily because not all of the analytical results of each sample were described completely. For example, IRDMS does not differentiate between total and dissolved water concentrations or clearly identify split and duplicate samples. Furthermore, it was not possible to determine if a compound was tentatively or positively identified in a given sample. An attempt was made to obtain more complete information regarding the data reported in IRDMS, but in some cases it was not possible to contact the persons who conducted the study from which the data were derived.

4.5.3 UNCERTAINTIES ASSOCIATED WITH THE MODELS AND ASSUMPTIONS USED TO ESTIMATE EXPOSURES

The assumptions regarding parameters used to quantify exposure can contribute to uncertainty in exposure estimates and the consequent estimates of risks. For example, uncertainties are associated with assumptions of how often, if at all, an individual would come into contact with the chemicals of concern and the period of time over which such exposures would occur. The assumptions made regarding periods of exposure are generally conservative and may overestimate the risks associated with potential exposure to chemicals in the various media evaluated. It also is possible that the assumed exposure parameters could underestimate exposures in a very small segment of the population.

Other parameter values used in the risk assessments (e.g., ingestion of 2 liters of water per day, 70-kg average body weight) are assumed to represent upper bounds of potential exposure and were used when site-specific data are not available. Risks for individuals within an exposed population are higher or lower depending on their actual drinking water intakes, body weights, etc.

4.5.4 UNCERTAINTIES ASSOCIATED WITH THE TOXICITY ASSESSMENT

The toxicity assessment also contributes to the uncertainty in the risk assessment, both because of the lack of adequate toxicity data to develop toxicity values, and because of the uncertainty surrounding any toxicity values that are developed.

For example, some chemicals were not included in the quantitative risk assessment because too few data are available to assess dose-response relationships quantitatively. In other cases, toxicity values were derived for this assessment based on the available toxicity studies, even though EPA-approved toxicity values have not been developed. Given the limited data upon which they are based, the toxicity values derived specifically for this assessment have a large degree of uncertainty. This uncertainty has largely been compensated for by the use of conservative procedures in toxicity criteria development. For the ecological assessment, the issue of toxicity information is more critical, because in many cases there is no ecological toxicity information for many of the chemicals present at the APG study areas.

In addition to the absence of adequate toxicity information, there are inherent uncertainties associated with the toxicity assessment procedure in general. Toxicological data error is a large source of uncertainty in risk assessment. EPA (1986a) noted that there are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic factors, diet, occupational and home environment, activity patterns, and cultural factors.

Assessing the toxicity of a mixture of chemicals involves a great deal of uncertainty. In this assessment, the effect of exposure to each contaminant present in the environmental media was considered separately. These substances occur together at the site, however, and individuals may be exposed to mixtures of the chemicals. Prediction of how these mixtures of toxicants interact must be based on an understanding of the mechanisms of such interactions. The interactions of the individual components of chemical mixtures may occur during absorption, distribution, metabolism, excretion, or activity at the receptor site. Individual compounds may interact chemically, yielding a new toxic component or causing a change in the biological availability of an existing component, or may interact by causing different effects at different receptor sites. Suitable data are not currently available to rigorously characterize the effects of chemical mixtures similar to those present at the various APG study areas. Consequently, as recommended by EPA (1986c), chemicals present at APG study areas were assumed to act additively, and potential health risks were evaluated by summing excess cancer risks for chemicals exhibiting carcinogenic effects and calculating Hazard Indices for chemicals exhibiting noncarcinogenic effects. This approach to assessing the risk associated with chemical mixtures assumes that there are no synergistic or antagonistic interactions among the chemicals considered and that all chemicals have the same toxic end points and mechanisms of action. To the extent that these assumptions are incorrect, the actual risk could be under- or overestimated.

4.6 PRINCIPAL DATA NEEDS

This section identifies additional data needed to evaluate more completely human health or ecological risks at each study area. For many of the APG study areas, additional data on the type and extent of chemical contamination are needed, including:

- Site-specific background concentrations of naturally occurring inorganic chemicals;
- Chemical analyses for the full range of chemicals that may be present at the site, including the wide variety of military-unique compounds potentially present, such as chemical agents and their breakdown products, munitions and related compounds, and smoke and incendiary materials;
- Chemical analyses for all potentially contaminated media (not all media have been sampled at all study areas); and
- Additional samples from all media to better characterize the extent of contamination as well as to characterize regular and irregular temporal variations in chemical contamination levels (e.g., as a result of diurnal tidal cycles or seasonal variations in precipitation or storm events).

4.7 SUMMARY AND CONCLUSIONS

In this section, the primary features of the risk assessment are summarized, and the principal conclusions are presented.

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5.0 O-FIELD RISK ASSESSMENT

This chapter evaluates potential impacts on human health and the environment associated with the O-Field study area in the absence of remedial (corrective) actions. The hydrogeologic field investigation conducted by USGS and summarized in USGS (1988, 1989) is the primary source of sampling data considered in this risk assessment. This study was selected for use in risk assessment because it was the most recent and comprehensive study conducted at O-Field. Data from other studies conducted at O-Field are briefly discussed where applicable to support evaluations of potential exposures or risks.

These and other investigations conducted to date have not completely characterized the nature and extent of contamination at O-Field. Therefore, this risk assessment should be considered largely preliminary and is intended as an initial step in the overall risk assessment process for O-Field.

This assessment follows the general methodology outlined in Chapter 4 of this report, which should be consulted for the rationale and further details of the methods used in this assessment. This assessment is organized into eight primary sections:

- Section 5.1 Background Information
- Section 5.2 Selection of Chemicals of Potential Concern
- Section 5.3 Human Health Risk Assessment
- Section 5.4 Ecological Assessment
- Section 5.5 Uncertainties
- Section 5.6 Principal Data Needs
- Section 5.7 Summary and Conclusions
- Section 5.8 References

5.1 BACKGROUND INFORMATION

O-Field is a hazardous waste and ordnance disposal site located on the Gunpowder Neck in the Edgewood Area of APG. The area was used for the disposal of chemical-warfare agents, munitions, contaminated equipment, and various other hazardous waste materials during the 1940s and early 1950s. It is bounded by Watson Creek and its associated marsh to the north and east and to the west by Watson Creek Road and the Gunpowder River (see Figure 5-1).

The O-Field study area consists of two separate areas: Old O-Field and New O-Field. Old O-Field is a 4.5-acre, fenced site located adjacent to the southwestern portions of Watson Creek. The field is situated on a local topographic high with a 4-6 foot relief across the field. The natural topography is interrupted by excavations within the fenced area, including an open trench along the east side of Old O-Field, and several partially closed pits. New O-Field occurs approximately 1,200 feet directly south of Old O-Field and is adjacent to the marsh that borders the southwestern portion of Watson Creek. New O-Field is not fenced. Terrain at New O-Field is relatively flat, but is interrupted by depressions where trenches or disposal pits exist. Groundwater flow from both Old and New O-Field is generally to the north towards Watson Creek and/or the Gunpowder River.

The disposal history at Old and New O-Field is not well known. What is known is based primarily on testimony, limited documentation, and survey notes. Because records are largely absent and most of the people associated with the disposal operations are deceased, it is unlikely that a significantly more detailed disposal history can be developed without on-site sampling and investigation. Table 5-1 lists the principal compounds believed to have been disposed of at O-Field.

Figure 5-1
O-Field Study Area

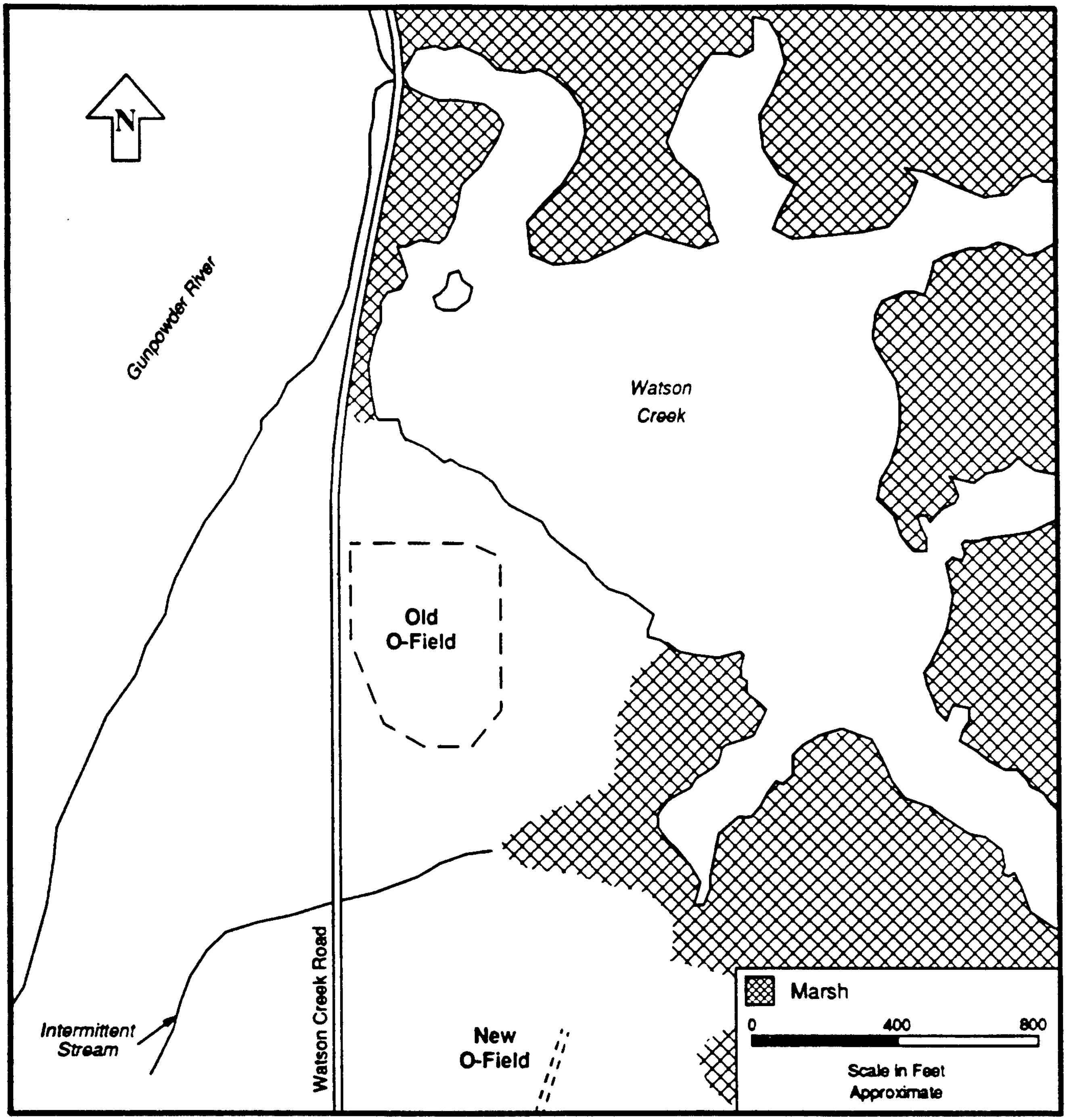

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TABLE 5-1

PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT O-FIELD (a)

Group	Chemical Compound (Acronym) (b)
Lethal Chemical Agents	Mustard (H or HD)
	Lewisite (L)
	Lewisite oxide (LO)
	Phosgene (CG)
	Cyanogen chloride (CK)
	Hydrogen cyanide (AC)
	Tabun (GA)
	Sarin (GB)
	Soman (GD)
	VX
Incapacitating Agents	Adamsite (DM)
	a-Chloroacetophenone (CN)
	CNS
	o-Chlorobenzylidene malononitrile (CS)
	Chloropicrin (PS)
	CNB/CNC
Smoke/Incendiary Materials	Phosphorus (WP and PWP)
	Sulfur trioxide-chlorosulfonic acid mixture (FS)
	Napalm
	HC
CC2 and CC3 Impregnating Materials	2,4,6-Trichlorophenylurea (TCPU)
Munitions Compounds	2,4,6-Trinitrotoluene (TNT)
	2,4-Dinitrotoluene (2,4-DNT)
	2,6-Dinitrotoluene (2,6-DNT)
	RDX
	HMX
	Tetryl
	Trinitrobenzene (TNB)
	Nitromethane
	Picric acid
CN Materials	Acetophenone
	Dichlorobenzophenone
	Benzophenone
Decontaminating Agents	Decontaminating agent - noncorrosive (DANC)
	Calcium hydroxide
Solvents	Various solvents including:
	Hexachloroethane (HCA) [major component of HC smoke]
	1,1,2,2-Tetrachloroethane [major component of DANC]
Miscellaneous Compounds	Methyl isopropyl ketone (MIPK)
	Cyclohexanone
	Methylcyclohexanone
	Methylquinoline
	Quinoline
	Diethylamine
	Benzonitrile
	Fuel oil constituents

(a) Information obtained primarily from: ICF (1987).

(b) See Glossary of Acronyms and Abbreviations for complete chemical name if not given in this table.

Old O-Field. Since World War II, Old O-Field has been used for the periodic disposal of waste materials for U.S. Army operations. During the period 1942-1953, 35 pits and trenches were dug at the field and used for the disposal of bulk chemical agents, munitions, contaminated equipment, and miscellaneous hazardous waste. The trenches were typically 20 feet wide and ranged in length from about 50 to 470 feet. The maximum depth of the trenches was at least 12 feet. Trenches were unlined and uncovered during their use.

In 1949, cleanup operations aimed at destroying some of the ordnance at Old O-Field were initiated by the Command of Technical Escort Detachment (Tec Escort). This operation included hand clearing and detonation of 4.2-inch boosters and bursters, 4.2-inch mortars, and the open burning of napalm and mustard. Explosions occurred periodically during the cleanup operation. One explosion exposed a pit that was reportedly lined with solid bombs. In response to these explosions, additional cleanup operations were initiated. As part of these efforts, approximately 1,000 drums of DANC (Decontaminating Agent Non-Corrosive) were dumped on the field possibly resulting in the release of up to 300,000 kg of 1,1,2,2-tetrachloroethane at the site (ICF 1987).

Some DANC and unknown quantities of lime (calcium hydroxide) were dispersed onto surrounding trees using TNT in an attempt to decontaminate mustard that had been dispersed throughout the area as a result of explosions in the disposal pits/trenches. A subsequent cleanup operation in 1953 involved soaking the field with fuel oil and allowing it to burn for several days.

New O-Field. The disposal pits at New O-Field were excavated in late 1950 as part of the cleanup efforts at Old O-Field (USGS 1989). The pits were about 20 feet wide and ranged in length from about 40 to 150 feet. The depth of the pits is not known but is probably similar to the pits at Old O-Field.

Although the records are incomplete, the wastes disposed at New O-Field were supposed to be burned daily. In later years, new pits were excavated roughly perpendicular to the original pits. These new pits were used as burn areas for wastes and are presently uncovered.

Some of the wastes believed to have been disposed at New O-Field are mustard, VX, white phosphorus, explosives, research lab wastes, acids, and veterinary wastes. No other records on waste disposal are available.

5.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

In this section, environmental monitoring data collected by USGS (1988, 1989) at O-Field are briefly summarized, and chemicals of potential concern are identified. Sampling data are available for subsurface soil, groundwater, surface water, and sediment. The discussions are organized below by these environmental media.

5.2.1 SUBSURFACE SOIL

USGS collected subsurface soil samples from four locations at Old O-Field (OF6, OF12, OF14, OF17) and from one location at New O-Field (OF16). Sample depths ranged between 7 and 85 feet. Chemical analyses were limited to arsenic, iron, manganese, and antimony. The rationale for choosing this limited list of analytes was not provided in the available documentation. The results of these analyses are summarized in Table 5-2.

TABLE 5-2

SUMMARY OF CHEMICALS DETECTED IN SUBSURFACE SOIL AT O-FIELD

(Concentrations reported in mg/kg)

Sample Location/ Chemical (a)	On-Site Concentration		Background (c)
	Arithmetic Mean (b)	Range	
OF6			
* Arsenic	9.1	0.84 - 22.4	6.0
Iron	4,680	1,700 - 7,310	70,000
Manganese	22.5	10 - 35.2	500
OF12			
Arsenic	0.96	0.38 - 1.46	6.0
Iron	5,397	2,290 - 11,600	70,000
Manganese	24.7	14.3 - 45.4	500
OF14			
Arsenic	2.21	1.81 - 2.49	6.0
Iron	8,050	4,700 - 10,300	70,000
Manganese	70.6	69.9 - 113	500
OF16			
Arsenic	1.71	0.77 - 2.65	6.0
Iron	4,430	4,180 - 4,680	70,000
Manganese	47.3	33.5 - 61.1	500
OF17			
Arsenic	1.11	1.11	6.0
Iron	2,550	2,550	70,000
Manganese	18.9	18.9	500

(a) Subsurface soil samples were analyzed for arsenic, iron, manganese, and antimony, only. Antimony was never detected at a detection limit of 0.32 mg/kg.
(b) Calculated for a soil boring across depth.
(c) Background concentrations from Boerngen and Shacklette (1981).
Location is Route 45, 2 miles north of Hereford, approximately 25 miles northwest of APG.
for soils were not available.
* = Selected as a chemical of potential concern. See text.

Antimony was not detected in any subsurface soil sample at a detection limit of 0.32 mg/kg. The other inorganic chemicals were detected at relatively low concentrations in all samples, with the exception of arsenic in sample OF6, which was detected at a maximum concentration of 22.4 mg/kg. This concentration appears to be slightly elevated relative to that detected in the other borings and in background soils and could reflect contamination associated with O-Field activities. Sample OF6 was collected adjacent to the disposal pits at Old O-Field; of the samples collected, it was located the closest to a potential source area. The other samples were collected from areas more distant but downgradient of the potential source areas, and therefore lower concentrations in these other samples could be reflective of subsurface contaminant distribution at the site. Too few samples were collected to make more definitive statements regarding subsurface contaminant distribution or the magnitude of any contamination, if present. Nevertheless, arsenic is selected as a chemical of potential concern for subsurface soils at O-Field based on the few sampling data that are available, primarily because arsenic-containing wastes are known to have been disposed of at O-Field.

5.2.2 GROUNDWATER

USGS collected groundwater samples from 21 downgradient wells at Old O-Field, 4 downgradient wells at New O-Field, and from 11 wells upgradient of both sites. Groundwater samples were collected approximately quarterly from most wells beginning in December 1985 and continuing through December 1986/February 1987. Some wells were sampled only once or twice. A few selected wells were sampled again in 1987.

Samples were analyzed for volatile and semivolatile organic chemicals and inorganic constituents in all sampling rounds. However, some inorganic chemicals were analyzed only once because they were not detected in the first sampling round (beryllium, lead, mercury, selenium, cyanide) at the detection limits (between 1 and 5 µg/L) or were detected in the first sampling round at concentrations below drinking water standards (chromium, copper, and nickel).

Groundwater samples from selected wells also were analyzed in September 1987 for the following agents and their breakdown products:

- Mustard;
- GB (Sarin);
- GD (Soman);
- VX;
- Ethyl methylphosphonic acid (hydrolysis product of VX);
- Methylphosphonic acid (hydrolysis product of VX and GB);
- Isopropyl methylphosphonic acid (hydrolysis product of GB);
- Pinacolyl methylphosphonic acid (hydrolysis product of GD);
- Thiodiglycol (hydrolysis product of mustard); and
- Chlorovinyl arsonic acid (oxidation product of lewisite).

Groundwater samples from selected wells were analyzed in December 1986 and/or September 1987 for the following explosives and related compounds:

- TNT;
- 2,4-DNT;
- 2,6-DNT;
- HMX;
- RDX:
- 1,3,5-Trinitrobenzene (1,3,5-TNB);
- 1,3-Dinitrobenzene (1,3-DNB);
- Nitrobenzene; and
- Tetryl.

Radiological parameters (gross beta, gross alpha, tritium, and cesium-137) and herbicides (2,4-D, Silvex, 2,4,5-T) were analyzed in single groundwater samples from selected wells.

Groundwater samples were collected from varying depths to characterize potential contamination in the three uppermost aquifers at O-Field: the water-table aquifer, the upper confined aquifer, and the lower-confined aquifer. The results of this sampling are summarized below for Old and New O-Fields separately. Data from water-table and upper-confined aquifer wells are summarized together and separate from that for the lower-confined aquifer. Lithologic logs of the area indicate a discontinuous confining layer between the two uppermost aquifers (collectively referred to here as shallow aquifers), indicating a hydraulic connection between the two is likely. However, the shallow aquifers appear to be separated completely from the lower-confined (deep) aquifer by a continuous and thick clay layer. Therefore, data from the deeper aquifer are summarized separately.

5.2.2.1 Old O-Field

Nineteen shallow and two deep downgradient wells were sampled at Old O-Field. Table 5-3 presents the frequency of detection and range of concentrations for the chemicals detected in downgradient wells along with information on chemical concentrations in upgradient wells near O-Field. A t-test was conducted to identify chemicals that were detected in shallow downgradient wells at concentrations statistically elevated compared to background. (See Chapter 4 for methodology.) A t-test could not be conducted for the deep wells because only a single deep background well was sampled. Therefore, downgradient concentrations were compared to the single background concentration and considered to be site related if the maximum downgradient concentration exceeded twice the background concentration (see Chapter 4).

5.2.2.1.1 Shallow Groundwater

Monitoring data for the shallow groundwater indicate that it is highly contaminated. A variety of volatile organic chemicals (VOCs) were detected frequently and at relatively high (>1,000 µg/L) maximum concentrations in Old O-Field shallow groundwater. The VOCs consist of benzene and substituted aromatics (toluene, ethylbenzene, and chlorobenzene), several chlorinated alkanes (carbon tetrachloride, chloroform, 1,2-dichloroethane, 1,1,2-trichloroethane and 1,1,2,2-tetrachloroethane), and chlorinated alkenes (vinyl chloride, 1,1-dichloroethene, 1,2-dichloroethene, trichloroethene, tetrachloroethene). A few of these chemicals were also detected in upgradient wells (suggesting other potential sources in the area), but at concentrations significantly lower (statistically) than those detected in downgradient wells.

Under anaerobic or oxygen depleted conditions, chlorinated alkanes and alkenes have been found to undergo reductive dechlorination reactions in groundwater, that is, reactions which sequentially remove chlorine from and add hydrogen to the chemical (Bouwer et al. 1981, Kobayashi and Rittman 1982). The transformation is sequential with, for example, tetrachloroethene yielding trichloroethene, which in turn yields 1,2-dichloroethene and ultimately vinyl chloride (Parsons et al. 1984, Cline and Viste 1984). Chloroform has been found to degrade to methylene chloride in laboratory studies (Bouwer 1983). An examination of the chemicals measured in shallow groundwater indicates that such transformations are occurring. Elevated concentrations of 1,2-dichloroethene and vinyl chloride have been measured together with their precursors tetrachloroethene and trichloroethene. Methylene chloride has been measured together with its precursors carbon tetrachloride and chloroform. 1,1,2,2-Tetrachloroethane has been measured together with its dechlorination products 1,1,2-trichloroethane and 1,2-dichloroethane.

TABLE 5-3

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT OLD O-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	
		On-Site	Background (d)
SHALLOW AQUIFERS (e)			
Organic Chemicals:			
* Benzene (C6H6)	15 / 19	1.1 - 2,850	0.4
* Carbon Tetrachloride (CCL4)	4 / 19	124 - 378	ND
* Chlorobenzene (CLC6H5)	10 / 19	1.5 - 210	ND
* Chloroform (CHCL3)	13 / 19	1.4 - 8,440	3.0 - 125
* 1,2-Dichloroethane (12DCLE)	14 / 19	1.1 - 1,100	ND
* 1,1-Dichloroethene (11DCE)	2 / 5	7.0 - 14	ND
* 1,2-Dichloroethene (total) (12DCE)	17 / 19	1.8 - 2,260	1.7 - 2.6
* 1,3-Dinitrobenzene (13DNB)	2 / 4	23.3 - 71.8	ND
* Ethyl Benzene (ETC6H5)	2 / 5	17.4 - 64.2	ND
* Methylene Chloride (CH2CL2)	11 / 13	5.0 - 667	14.3 - 173
* Methylphosphonic Acid (MPA)	1 / 12	10,000	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	15 / 19	1.8 - 9,120	5.9
* Tetrachloroethene (TCLEE)	9 / 19	1.4 - 1,770	ND
* Thiodiglycol (TDGCL)	10 / 12	1,000 - 1,000,000	NA
* Toluene (MEC6H5)	14 / 19	1.2 - 209	0.7 - 1.0
* 1,1,2-Trichloroethane (112TCE)	7 / 19	4.1 - 219	ND
* Trichloroethene (TRCLE)	13 / 19	1.3 - 3,430	1.0
* 2,4,6-Trinitrotoluene (246TNT)	1 / 8	22.1	NA
* Vinyl Chloride (C2H3CL)	9 / 19	2.3 - 1,430	0.9
Inorganic Chemicals:			
Ammonia (NH3)	19 / 19	21.7 - 5,500	153 - 2,320
Ammonia Nitrogen (NH3N2)	16 / 19	47.7 - 2,930	27.0 - 1,920
* Antimony (SB)	14 / 19	3.1 - 56.8	1.4 - 4.8
* Arsenic (AS)	14 / 19	1.7 - 1,250	1.3 - 22.1
* Boron (B)	17 / 19	70.5 - 4,740	173 - 527
Bromide (BR)	8 / 14	234 - 2,900	ND
Calcium (CA)	19 / 19	9,280 - 94,500	2,470 - 39,100
Chloride (CL)	19 / 19	6,570 - 2,150,000	3,200 - 23,100
* Fluoride (F)	17 / 19	85.0 - 293	51.7 - 200
* Iron (FE)	19 / 19	109 - 245,000	44.0 - 21,600
Magnesium (MG)	19 / 19	3,040 - 105,000	2,080 - 9,780
* Manganese (MN)	19 / 19	119 - 7,500	88.0 - 1,210
Nitrate (NO3)	17 / 18	10.0 - 2,630	20.0 - 2,401
Nitrite (NO2)	16 / 19	17.5 - 194	22.5 - 3,060
Phosphorus (P4)	19 / 19	18.0 - 4,100	43.0 - 1,060
Potassium (K)	19 / 19	589 - 27,500	890 - 3,150
Sodium (NA)	19 / 19	6760 - 859,000	770 - 21,700
Sulfate (SO4)	19 / 19	6,110 - 324,000	15,400 - 55,800
* Sulfide (SULFID)	5 / 19	3,250 - 8,400	ND
* Zinc (ZN)	19 / 19	16.8 - 6,100	6.0 - 64.2
Radiological Parameters (pCi/L):			
* Gross Beta (BETAG)	4 / 4	2.3 - 8.5	NA

See footnotes on the following page.

TABLE 5-3 (Continued)

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT OLD O-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	
		On-Site	Background (d)
DEEP AQUIFER (f)			
Inorganic Chemicals:			
Ammonia (NH3)	2 / 2	1,680 - 1,820	2,302
Ammonia Nitrogen (NH3N2)	2 / 2	112 - 327	3,210
* Antimony (SB)	2 / 2	2.1 - 4.3	1.1
* Arsenic (AS)	2 / 2	1.2 - 4.0	1.3
Boron (B)	2 / 2	419 - 626	442
Bromide (BR)	1 / 2	415	ND
Calcium (CA)	2 / 2	14,100 - 20,000	25,100
Chloride (CL)	2 / 2	5,140 - 149,00	3,800
Fluoride (F)	2 / 2	150 - 266	188
Iron (FE)	2 / 2	13,900 - 20,700	15,800
Magnesium (MG)	2 / 2	4,380 - 7,390	5,310
Manganese (MN)	2 / 2	412 - 524	686
Nitrate (NO3)	2 / 2	33.0 - 59.0	39.2
Nitrite (NO2)	2 / 2	25.0 - 30.0	26.0
Phosphorus (P4)	2 / 2	1,340 - 1,950	69.6
Potassium (K)	2 / 2	2,220 - 5,760	4,790
Sodium (NA)	2 / 2	19,000 - 22,500	8,450
* Sulfate (SO4)	2 / 2	11,100 - 25,800	3,420
* Sulfide (SULFID)	1 / 2	2,700	ND
* Zinc (ZN)	2 / 2	48.6 - 66.0	12.8

(a) USATHAMA chemical codes in parentheses.
(b) The number of samples in which the chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Values reported are dissolved concentrations. Total concentrations were not measured as part of this study.
(d) Samples: For shallow aquifers -- OF1, OF3, OF5, OF7, OF9, OF10, OF11, OF18A, OF18B, and OF19; for deep aquifer -- OF18C.
(e) Samples: OF6, OF6A, OF6B, OF12A, OF12B, OF12C, OF13A, OF13B, OF13C, OF14A, OF14B, OF14C, OF17A, OF17B, OF20A, OF20B, OF21, OF22A, and OF22B.
(f) Samples: OF6C and OF14D.

ND = Not detected.
NA = Not analyzed. Samples were not analyzed for this parameter.
* = Selected as a chemical of potential concern. See text.

Thiodiglycol, methylphosphonic acid, TNT, and 1,3-dinitrobenzene were the only other organic chemicals positively identified in Old O-Field shallow groundwater. Thiodiglycol, a hydrolysis product of mustard, was detected frequently (10/12 samples) and at high concentrations (1,000-1,000,000 µg/L). The widespread presence of thiodiglycol in groundwater suggests that there may be an existing mustard source in contact with the groundwater at Old O-Field and that transformation to sulfoxides or sulfones is not favorable under existing conditions. Methylphosphonic acid, a hydrolysis product of GB and VX, was detected only once, but at a relatively high concentration (10,000 µg/L). Its true distribution in the shallow groundwater at Old O-Field could be masked by relatively high detection limits (400 µg/L) achieved in the analyses. However, the high concentration reported for the single sample in which it was detected suggests that there may be a large source of GB or VX in contact with the groundwater. TNT was detected in a single sample and at a relatively low concentration, and 1,3-dinitrobenzene was detected in two samples, also at relatively low concentrations. These nitroaromatics, which tend to undergo reduction at the nitro group to form various amino-substituted aromatics, have not been detected at O-Field (see discussion of tentatively identified compounds below). None of the other agents, explosives, or related chemicals analyzed for were detected in groundwater. However, the detection limits for the nerve agent and lewisite degradation products were relatively high (>400 µg/L and 40 µg/L, respectively), and these other compounds could be present in O-Field groundwater at concentrations below these detection limits. No herbicides were detected in groundwater at detection limits of less than 1 µg/L.

Groundwater concentration contours generated by USGS (1988) and ICF (1990) show that the maximum concentrations of most of the organic chemicals detected in shallow groundwater are located nearest the Old O-Field disposal pit/trench area, and that concentrations decrease downgradient of this area towards Watson Creek, where shallow groundwater discharges. In fact, maximum and arithmetic mean concentrations of the organic chemicals are substantially lower in wells located closest to Watson Creek. Table 5-4 presents summary concentration information for wells located nearest Watson Creek.

All organic chemicals detected in Old O-Field groundwater were selected as chemicals of potential concern.

A variety of inorganic chemicals were also detected in the shallow groundwater at Old O-Field. All inorganic chemicals except ammonia, ammonia nitrogen, nitrate, nitrite, and sulfate were detected in Old O-Field groundwater at concentrations statistically elevated above background concentrations. All remaining chemicals, excluding those of relatively low toxicity (bromide, cadmium, chloride, magnesium, phosphorus, potassium, sodium; see Chapter 4 for discussion), were selected as chemicals of potential concern. Gross beta was selected as a parameter of concern.

5.2.2.1.2 Deep Groundwater

None of the positively identified organic chemicals found often at high concentrations in shallow groundwater were detected in deep groundwater at Old O-Field. These results support the belief that there is a continuous confining layer separating the deeper groundwater from the contamination in shallow O-Field groundwater.

Several inorganic chemicals were detected in deep groundwater. Of these, antimony, arsenic, sulfate, sulfide, and zinc are considered to be above background concentrations, and were selected as chemicals of potential concern. Several other inorganic chemicals are considered above background, but were not selected as chemicals of potential concern because of their low toxicity (bromide, chloride, phosphorus and sodium).

TABLE 5-4

SUMMARY OF CHEMICALS DETECTED IN O-FIELD GROUNDWATER NEAR WATSON CREEK (a)

(Concentrations reported in ug/L)

Chemical (b)	Range of Detected Concentrations	Arithmetic Mean Concentration
1,1,2,2-Tetrachloroethane (TCLEA)	1.8 - 3,200	690
1,1,2-Trichloroethane (112TCE)	219	28
1,2-Dichloroethane (12DCLE)	1.1 - 1,100	190
1,2-Dichloroethene (total) (12DCE)	1.8 - 2,300	600
1,3-Dinitrobenzene (13DNB)	23.3 - 71.8	24
1,4-Dithiane (DITH) (c)	24 - 927	150
Benzene (C6H6)	1.3 - 1,110	200
Carbon Tetrachloride (CCL4)	378	48
Chlorobenzene (CLC6H5)	73.6 - 156	42
Chloroform (CHCL3)	1.4 - 1,820	300
Methylene Chloride (CH2CL2)	2.2 - 228	68
Methylphosphonic Acid (MPA)	10,000	1,600
Tetrachloroethene (TCLEE)	33 - 392	94
Thiodiglycol (TDGCL)	1,000 - 200,000	31,000
Toluene (MEC6H5)	2.4 - 57	13
Trichloroethene (TRCLE)	31.8 - 3,430	530
Vinyl Chloride (C2H3CL)	2.3 - 1,430	200

(a) Samples: 14A, 14B, 14C, 20A, 20B, 21, 22A, and 22B.
(b) USATHAMA chemical codes listed in parentheses.
(c) Samples: 14A, 14B, 14C, 21, and 22.

The concentrations of the selected inorganic chemicals in deep groundwater are substantially below those detected in the shallow groundwater. For example, the maximum concentration of arsenic in deep groundwater is approximately 300 times lower than that reported for shallow groundwater, and that of zinc is approximately 100 times lower. The relatively low concentrations of these inorganic chemicals in groundwater in conjunction with the lack of any organic contaminants in deeper groundwater may indicate that the inorganic chemicals detected in deeper groundwater are present as a result of natural background levels. As noted above, only one background sample was available for this aquifer. Additional background data for the deeper aquifer would help determine if the inorganic chemicals in the deep aquifer are indicative of contamination.

5.2.2.1.3 Tentatively Identified Compounds (TICs)

A large number of chemicals were tentatively identified in shallow and deep groundwater samples from Old O-Field; a few of these chemicals were also measured in deep groundwater samples. Table 5-5 summarizes concentration and frequency data for the TICs identified in Old O-Field groundwater. By far, the largest number of TICs were reported for shallow groundwater. The measurement of trace levels of TICs in deep groundwater could be due to inadvertent contamination during well construction, given that downward migration of contaminants is not likely because of the probable presence of a confining layer between shallow and deep aquifers. Alternatively, the presence of TICs in deep groundwater may suggest that the confining layer is not continuous across the entire site. Most of these chemicals were detected infrequently (three or fewer samples) and at relatively low concentrations (<100 µg/L). However, a few chemicals were reported in a larger number of samples (methylnaphthalenes) and/or at higher concentrations (dioctyl adipate, methyl ethyl ketone, a C3-substituted benzene). 1,4-Dithiane, tentatively identified in 14 samples, was the most frequently reported TIC. This chemical was also reported at the highest concentration (5,150 µg/L) of any TIC. 1,4-Dithiane is a thermal degradation product of mustard and is probably present in groundwater as a result of past demilitarization operations at Old O-Field. It is very soluble in water and would not tend to adsorb appreciably to soil; it is therefore extremely mobile in the subsurface environment.

TICs are typically not selected for quantitative evaluation in risk assessments because of the uncertainty surrounding their identity and concentrations. 1,4-Dithiane was selected as a chemical of potential concern for Old O-Field because of its apparent widespread distribution and high concentrations in Old O-Field groundwater. The other TICs were not selected for further evaluation but could add significantly to estimates of exposures and risks. The implications of excluding these TICs from the risk assessment is discussed in the uncertainty section.

5.2.2.2 New O-Field

Four shallow downgradient wells were sampled at New O-Field. Table 5-6 presents the frequency of detection and range of concentrations for the chemicals detected in downgradient wells along with information on chemical concentrations in shallow upgradient wells near O-Field. Again, a t-test was conducted to identify chemicals that were detected in shallow downgradient wells at concentrations statistically elevated compared to background. (See Chapter 4 for methodology.)

As was the case at Old O-Field, a variety of VOCs were detected in New O-Field groundwater. However, most of the VOCs detected at New O-Field were present at maximum concentrations 10-1,000 times lower than those reported for Old O-Field. The exceptions to this are 1,2-dichloroethene and vinyl chloride, which were detected at higher concentrations at New O-Field than at Old O-Field.

TABLE 5-5

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN OLD O-FIELD GROUNDWATER

(Concentrations reported in ug/L)

Chemical (a)	Number of Detects (b)	Range of Reported Concentrations (c)
SHALLOW AQUIFERS (d)		
Acetone (ACET)	2	38 - 125
C3 Benzene/C3 Alkyl Benzene	4	5 - 1,850
Benzoic Acid (BENZOA)	1	1
1,1'-Bicyclohexyl (BICYHX)	2	2 - 4
Butanoic Acid, 2-Methyl, Methyl Ester	1	16
Carbon Disulfide (CS2)	2	15 - 17
4-Carene	1	10
Chlorobenzene	1	37
Chlorocarbon	1	4
Cyclohexane (CYHX)	2	1 - 2
Cyclohexanol (C6HOH)	1	2
Cyclohexanone (CHONE)	1	2
Dichlorobenzene (DCLB)	1	10
3,5-Dimethyl-1,2,4-trithiolane	1	115
Dioctyl Adipate (DOAD)	8	6 - 373
1,4-Dioxane (14DIOX)	2	2 - 67
1,4-Dithiane (DITH)	14	3 - 5,150
1,3-Dithiolane-2-thione	1	52
Dithione/Substituted Dithione	1	3 - 110
Ethanol,2,2'-(1,2-ethanediyl)-bis(thio)bis	2	50 - 127
2-Fluoro-2-methylpropane	1	7
Heptane	1	4
2-Hydroxybenzoic Acid, Methylester	2	28 - 47
1(3H)-Isobenzofuranone	1	15
6-Methyl-1,3-oxathiane	1	21
2-Methyl-3-Pentanone (2M3PNO)	1	1
4-Methyl-2-pentanone	1	4
5-Methyl-5-phenyl-2-hexanone	1	1
Methyl Cyclohexane (MECC6)	2	6 - 7.00
Methyl Ethyl Ketone (MEK)	3	4 - 5,000
Methyl Isopropyl Ketone (MIPK)	1	25
Methylnaphthalenes (METLAP)	4	1 - 40
2-Methylquinoline	2	21 - 49
Methylquinoline Isomer	1	53
Pentafluorophenol Derivative	1	5
Pentafluorophenone Derivative	1	3.0
1,2,3-Propanetriol	1	4.0
Sulfur (S)	1	6
1,1,1,2-Tetrachloroethane (2TCLEA)	2	2 - 4
1,1,2,2-Tetrachloroethane (TCLEA)	1	197
Tetrahydrofuran (THF)	1	4
Thiirane	1	5.0
Thiophene (TPH)	2	9 - 12
DEEP AQUIFER (e)		
Acetone (ACET)	1	14.0
Cyclohexanol (C6HOH)	1	1
1,4-Dioxane (14DIOX)	1	53
1,4-Dithiane (DITH)	1	3
Methylnaphthalenes (METLAP)	1	1
1-Pentene	1	5
Sulfur (S)	1	3

(a) USATHAMA chemical codes listed in parentheses.
(b) Number of samples in which the chemical was tentatively identified.
(c) Values reported are dissolved concentrations. Total concentrations were not measured as part of this study.
(d) Samples: OF6, OF6A, OF6B, OF12A, OF12B, OF12C, OF13A, OF13B, OF14A, OF14B, OF14C, OF17A, OF17B, OF19A, OF21, OF22, OF23, and OF24.
(e) Samples: OF6C and OF14D.

TABLE 5-6

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT NEW O-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	
		Downgradient	Upgradient (e)
SHALLOW AQUIFERS (f)			
Organic Chemicals:			
* Benzene (C6H6)	2 / 4	24.2 - 39.8	0.4
* Chlorobenzene (CLC6H5)	2 / 4	2.3 - 8.4	ND
* Chloroform (CHCL3)	1 / 4	5.2	3.0 - 125
* 1,2-Dichloroethane (12DCLE)	2 / 4	2.2 - 5.1	ND
* 1,2-Dichloroethene (total) (12DCE)	2 / 4	373 - 3,430	1.7 - 2.6
* Methylene Chloride (CH2CL2)	2 / 3	33.8 - 201	14.3 - 173
* Methylphosphonic Acid (MPA)	1 / 2	>10,000	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	2 / 4	3.4 - 17.7	5.9
* Tetrachloroethene (TCLEE)	2 / 4	9.7 - 332	ND
* Toluene (MEC6H5)	2 / 4	11.6 - 18.1	0.7 - 1.0
* 1,1,2-Trichloroethane (112TCE)	1 / 4	3.3	ND
* Trichloroethene (TRCLE)	2 / 4	4.4 - 180	1.0
* Vinyl Chloride (C2H3CL)	2 / 4	321 - 3,480	0.9
Inorganic Chemicals:			
Ammonia (NH3)	3 / 4	68.0 - 5,030	153 - 2,320
Ammonia Nitrogen (NH3N2)	3 / 4	250 - 1,240	27.0 - 1,920
Antimony (SB)	4 / 4	1.7 - 5.7	1.4 - 4.8
Arsenic (AS)	2 / 4	2.2 - 6.7	1.3 - 22.1
Boron (B)	4 / 4	95.2 - 2,650	173 - 527
Bromide (BR)	2 / 4	236 - 300	ND
Calcium (CA)	4 / 4	4,770 - 61,200	2,470 - 39,100
Chloride (CL)	4 / 4	2,200 - 108,000	3,200 - 23,100
Fluoride (F)	3 / 4	85.0 - 272	51.7 - 200
Iron (FE)	4 / 4	9.0 - 34,900	44.0 - 21,500
Magnesium (MG)	4 / 4	2,950 - 104,000	2,080 - 9,780
Manganese (MN)	4 / 4	24.0 - 1,350	88.0 - 1,210
Nitrate (NO3)	4 / 4	208 - 68,400	20.0 - 2,400
Nitrite (NO2)	2 / 4	305 - 385	22.5 - 3,100
Phosphorus (P4)	4 / 4	12.0 - 3,270	43.0 - 1,060
Potassium (K)	4 / 4	167 - 21,000	890 - 3,150
Sodium (NA)	4 / 4	2,960 - 76,000	770 - 21,700
Sulfate (SO4)	4 / 4	22,000 - 108,000	15,400 - 55,800
Zinc (ZN)	4 / 4	16.0 - 31.8	6.0 - 64.2

(a) USATHAMA chemical codes in parentheses.
(b) The number of samples in which the chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Values reported are dissolved concentrations. Total concentrations were not measured as part of this study.
(d) Samples: OF2, OF8, OF16A, and OF16B.
(e) Samples: OF1, OF3, OF5, OF7, OF9, OF10, OF11, OF18A, OF18B, and OF19.
(f) No samples were collected from the deep aquifer at New O-Field.

ND = Not detected.
NA = Not analyzed. Samples were not analyzed for this parameter.
* = Selected as a chemical of potential concern. See text.

Several of the VOCs were detected at concentrations that were not significantly (statistically) elevated over those in upgradient samples. This may indicate that there may be an upgradient source of contamination and that the detected concentrations at New O-Field are unrelated to past activities at New O-Field or that there was cross-contamination of samples. Nevertheless, all organic chemicals detected in shallow groundwater were selected as chemicals of potential concern for New O-Field since they are not naturally occurring chemicals and are indicative of some source of contamination.

None of the inorganic chemicals detected in shallow groundwater at New O-Field were present at concentrations significantly elevated above background, and therefore, no inorganic chemicals were selected as chemicals of potential concern for New O-Field.

Several TICs were detected in the shallow groundwater. Table 5-7 summarizes concentration and frequency data for the TICs identified in New O-Field groundwater. Dioctyl adipate was the TIC reported at the highest concentration (411 µg/L). This chemical could be present as a result of laboratory contamination as it is commonly present in general purpose plasticizers. It was not, however, detected in the corresponding method blanks. Plasticized white phosphorus (PWP) demilitarization and/or disposal at New O-Field is another potential source of this compound. The remaining TICs were detected at relatively low concentrations (i.e., generally <30 µg/L). None of the TICs are selected as chemicals of potential concern for New O-Field groundwater. However, one of these (1,4-dithiane) was selected for Old O-Field groundwater because of the higher concentrations observed there.

5.2.3 SURFACE WATER

Surface water samples were collected in August 1985 from 20 sites throughout Watson Creek and from 3 sites in the Gunpowder River near the mouth of Watson Creek. Several of these samples were collected along the southwestern shore of Watson Creek where groundwater is known to discharge. Additional surface water samples were collected from selected Watson Creek sites in 1987 and January 1988. Surface water samples were analyzed for volatile and semivolatile organic chemicals and inorganic chemicals.

Table 5-8 summarizes the surface water sampling data for Watson Creek and the Gunpowder River near Watson Creek and also presents background concentrations from surface waters located near APG. No site-specific background surface water samples were collected as part of the USGS study. Therefore, O-Field surface water data are compared to these other background data to identify inorganic chemicals that may be site related (see Chapter 4 for data sources and comparison methodology). The general appropriateness of these background data for such evaluations has been discussed in Chapter 4.

As the table shows, several VOCs were detected in Watson Creek surface water, but infrequently and at low concentrations. The VOCs in surface water correspond to those detected in groundwater at Old and New O-Field. The highest concentrations of VOCs were detected at site 8, which is located near the southwestern shoreline of Watson Creek near the location of groundwater discharge from Old O-Field. Most other VOCs detected also were detected in samples near the southwestern shoreline but were not detected in samples collected farther from the suspected discharge point, possibly because of dilution or volatilization from the creek. The exception to this is several VOCs that were detected during January 1988 sampling at site 1 (one of only two locations sampled in that sampling round), located at the mouth of Watson Creek. The creek was ice-covered during this sampling, and the presence of VOCs at a point distant from the suspected groundwater discharge area is probably due to reduced volatilization during the winter months and to the ice covering which could trap VOCs, resulting in higher concentrations in surface water. (Contaminated groundwater from O-Field does not

TABLE 5-7

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN NEW O-FIELD GROUNDWATER

(Concentrations reported in ug/L)

Chemical (a)	Number of Detects (b)	Range of Reported Concentrations (c)
SHALLOW AQUIFERS (d)		
Aniline (ANIL)	1	26
Chloroaniline	1	16
Cyclohexane (CYHX)	2	7
3,5-Dichloroaniline	1	20
Dichlorophenol (DICP)	1	23
2,2-Dimethyl-3-hexane	1	8
Dimethylbenzoic Acid	1	6
Dioctyl Adipate	2	5 - 411
Diphenylmethanone	1	7
1,4-Dithiane (DITH)	1	4.1
1-Ethenyl-2-methylbenzene	1	9
Ethyl-2-methylbenzene	1	21
Methylcyclohexane (MECC6)	1	4
Methylcyclopentane (MECYPE)	2	5 - 7
1-Methylethyl Benzene	1	60
Phosphonic Acid, Methyl-bis(1-methylethyl)ester	2	24 - 32
Trichloroaniline	2	2 - 19
Trimethylbenzene Isomer	1	2
Xylenes [Total] (XYLEN)	2	2 - 21

(a) USATHAMA chemical codes listed in parentheses.
(b) Number of samples in which the chemical was tentatively identified.
(c) Values reported are dissolved concentrations. Total concentrations were not measured as part of this study.
(d) Samples: OF2, OF8, OF16A, and OF16B. No samples were collected from the deep aquifer at Old O-Field.

TABLE 5-8

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT O-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
WATSON CREEK (e)			
Organic Chemicals:			
* Benzene (C6H6)	2 / 20	2.3 - 2.7	NA
* Carbon Tetrachloride (CCL4)	1 / 20	3.3	NA
* Chloroform (CHCL3)	2 / 20	3.3 - 49.3	NA
* 1,2-Dichloroethane (12DCLE)	1 / 20	62.5	NA
* 1,1-Dichloroethene (11DCE)	1 / 20	131	NA
* trans-1,2-Dichloroethene (T12DCE)	2 / 20	2.3 - 66.3	NA
* Di-n-octylphthalate (DNOP)	1 / 20	8	NA
* Ethyl Benzene (ETC6H5)	3 / 20	2.2 - 4.2	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	2 / 20	12.5 - 47.5	NA
* Trichloroethene (TRCLE)	2 / 20	2.3 - 18.3	NA
* Vinyl Chloride (C2H3CL)	1 / 20	26	NA
Inorganic Chemicals:			
* Antimony (SB)	18 / 18	10.6 - 149	<1
Arsenic [Total] (AS)	18 / 18	10.7 - 126	<1
* Arsenic III (ASIII)	18 / 18	27.8 - 95	NA
* Arsenic V (ASV)	14 / 14	1 - 66	NA
Bromide (BR)	6 / 6	10 - 10,500	NA
* Boron (B)	18 / 18	454 - 785	NA
* Cadmium (CD)	3 / 18	1.5 - 18	<1
Calcium (CA)	18 / 18	43,200 - 84,100	4,400 - 14,000
Chloride (CL)	6 / 6	2,300,000 - 3,180,000	12,000 - 46,000 (f)
* Copper (CU)	3 / 18	2.5 - 3.3	1
* Fluoride (F)	3 / 6	195 - 350	100 - 200
* Iron (FE)	18 / 18	51.6 - 794	15 - 530 (f)
Magnesium (MG)	18 / 18	133,000 - 274,000	2,000 - 7,100
* Manganese (MN)	18 / 18	468 - 874	10 - 100 (f)
* Mercury (HG)	11 / 18	0.2 - 0.4	0.1
Nitrogen (N2)	3 / 3	710 - 1,000	NA
Nickel (NI)	1 / 18	6	6
Nitrite (NO2)	2 / 3	140 - 150	100 - 5,300
Phosphorous (P4)	3 / 3	30 - 80	NA
Potassium (K)	18 / 18	59,700 - 72,700	1,000 - 3,000
* Selenium (SE)	18 / 18	28.8 - 94	<1
Sodium (NA)	18 / 18	1,310,000 - 2,180,000	6,700 - 21,000
* Sulfate (SO4)	7 / 7	378,000 - 960,000	7,000 - 21,000 (f)
Titanium (TI)	18 / 18	76 - 980	NA
* Zinc (ZN)	17 / 18	2 - 168	75
GUNPOWDER RIVER (g)			
Organic Chemicals:			
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 3	24	NA
Inorganic Chemicals:			
* Antimony (SB)	3 / 3	115 - 126	<1
* Arsenic [Total] (AS)	3 / 3	13 - 90	<1
Arsenic III (ASIII)	3 / 3	65 - 75	NA
Arsenic V (ASV)	2 / 2	5 - 15	NA
Bromide (BR)	2 / 2	11,500 - 12,200	NA
* Boron (B)	3 / 3	930 - 1,020	NA
Calcium (CA)	3 / 3	56,700 - 77,000	4,400 - 14,000
Chloride (CL)	2 / 2	3,060,000 - 3,150,000	12,000 - 46,000 (f)
Iron (FE)	3 / 3	34 - 54	15 - 530 (f)
Magnesium (MG)	3 / 3	168,000 - 216,000	2,000 - 7,100
* Manganese (MN)	3 / 3	396 - 562	10 - 100 (f)
Mercury (HG)	2 / 3	0.2	0.1
Nickel (NI)	1 / 3	5	6
Potassium (K)	3 / 3	68,400 - 73,700	1,000 - 3,000
* Selenium (SE)	3 / 3	45 - 53	<1
Sodium (NA)	3 / 3	1,480,000 - 1,880,000	6,700 - 21,000
* Sulfate (SO4)	2 / 2	414,000 - 473,000	7,000 - 21,000 (f)
Titanium (TI)	3 / 3	74 - 650	NA
Zinc (ZN)	2 / 3	8 - 10	75

See footnotes on the following page.

TABLE 5-8 (Continued)

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT O-FIELD

(Concentrations reported in ug/L)

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Total concentrations reported.
(d) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(e) Samples: 1 through 20.
(f) Total concentrations reported.
(g) Samples: 21, 22, and 23.

NA = Not available.
* = Selected as a chemical of potential concern. See text.

discharge near the mouth of Watson Creek.) All VOCs were selected as chemicals of potential concern for Watson Creek.

Di-n-octylphthalate was the only other organic chemical detected in Watson Creek surface water, and bis(2-ethylhexyl)phthalate was the only organic chemical detected in the Gunpowder River. Both chemicals were detected in a single sample and at low concentrations, but were nevertheless selected as chemicals of potential concern for O-Field surface water. Although both compounds are common laboratory contaminants, neither chemical was detected in its corresponding method blank. Because of the physicochemical properties of phthalates, it is most likely that they are adsorbed to suspended sediments and are not dissolved in surface water.

Several inorganic chemicals were detected in Watson Creek and Gunpowder River surface water at concentrations estimated to be above local background concentrations. They were therefore selected as chemicals of potential concern for these waters. These chemicals are designated in Table 5-8.

In general, concentrations of the selected chemicals in Watson Creek are slightly elevated over those detected in the Gunpowder River (by no more than a factor of 2). The biggest difference between Watson Creek and the Gunpowder River samples is in iron and zinc concentrations, which are greater than 15 times higher in Watson Creek than in the Gunpowder River. In addition, cadmium, copper, and fluoride were detected in Watson Creek but not in the Gunpowder River samples (at similar detection limits).

Three TICs were detected in both Watson Creek and Gunpowder River samples at low concentrations (<32 µg/L). Analytical data for these chemicals are presented in Table 5-9. None of these chemicals was selected as a chemical of potential concern for O-Field surface water.

5.2.4 SEDIMENT

Sediment samples were collected in 1985 from 30 sites throughout Watson Creek and from 4 sites within the Gunpowder River near the mouth of Watson Creek. Samples were analyzed for volatile and semivolatile chemicals and inorganic chemicals. Sample analytical results are summarized in Table 5-10 along with background sediment concentrations from surface waters located near APG. No site-specific background sediment samples were collected as part of the USGS study. Therefore, O-Field sediment data were compared to these other background data to identify inorganic chemicals that may be site related (see Chapter 4 for comparison methodology). The general appropriateness of these background data for such evaluations has been discussed in the Chapter 4.

The most frequently detected organic chemicals, phthalates and PAHs, were selected as chemicals of potential concern for Watson Creek. PAHs were not measured in the corresponding Watson Creek surface water samples, and one phthalate was measured in surface water most likely due to the presence of suspended sediment in the sample. It is not surprising that chemicals in these two classes were measured largely in sediment rather than surface water, because PAHs and phthalates in surface water would tend to partition or adsorb onto organic carbon present in sediment. It should be noted that the total PAH concentration in Watson Creek sediments is relatively low and similar to the PAH levels detected in sediments from other portions of the Chesapeake Bay. However, the fact that no PAHs were detected in the Gunpowder River sediments suggests that those in Watson Creek are related to past activities at O-Field (probably associated with the large-scale fires initiated as part of past demilitarization activities). Because a large number of organic chemicals were detected (>15), chemicals detected in fewer than 10% of the samples and at low concentrations were eliminated from further evaluation (see Chapter 4). Isophorone (a solvent used with lacquers, resins, and pesticides), 4-hydroxyacetophenone (a probable breakdown product of the tear agent CN), and cyclohexanol were

TABLE 5-9

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN O-FIELD SURFACE WATER

(Concentrations reported in ug/L)

Chemical	Number of Detects (a)	Range of Reported Concentrations
Watson Creek (b)		
Acetone (polymerized)	5	12 - 32
n-Hexane	1	1
5-Methyl-5-phenyl-2-hexanone	5	1 - 20
Gunpowder River (c)		
Bicyclohexyl	2	1
Dioctyl Adipate	1	11
n-Hexane	1	8

(a) Number of samples in which the chemical was tentatively identified.
(b) Samples: 1 through 10 and 13 through 20.
(c) Samples: 21 and 22.

TABLE 5-10

SUMMARY OF CHEMICALS DETECTED IN SEDIMENT AT O-FIELD

(Concentrations reported in mg/kg)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations	Background Concentration (c)
WATSON CREEK (d)			
Organic Chemicals:			
Cyclohexanol (C6HOH)	1 / 28	0.080	NA
4-Hydroxyacetophenone	1 / 28	0.060	NA
Isophorone (ISOPHR)	1 / 28	0.180	NA
* PAHs [carcinogenic]	3 / 28	1.50 - 4.67	3.8 - 6.4 (e,f)
Benzo(a)anthracene (BAANTR)	2 / 28	0.200 - 0.300	NA
Benzo(b)fluoranthene (BBFANT)	1 / 28	0.670	NA
Benzo(a)pyrene (BAPYR)	3 / 28	1.15 - 3.22	NA
Chrysene (CHRY)	1 / 28	0.480	NA
* PAHs [noncarcinogenic]	5 / 28	0.350 - 4.14	3.8 - 6.4 (e,f)
Anthracene (ANTRC)	3 / 28	0.140 - 0.210	NA
Fluoranthrene (FANT)	3 / 28	0.570 - 1.03	NA
Fluorene (FLRENE)	2 / 19	0.310 - 1.05	NA
Naphthalene (NAP)	3 / 28	0.260 - 0.360	NA
Phenanthrene (PHANTR)	5 / 28	0.150 - 1.15	NA
Pyrene (PYR)	4 / 28	0.400 - 0.805	NA
Phthalates			
Butylbenzylphthalate (BBZP)	2 / 28	0.160 - 0.260	NA
* Di-n-butylphthalate (DNBP)	5 / 28	0.550 - 1.55	NA
* Diethylphthalate (DEP)	8 / 28	0.154 - 2.36	NA
* Dimethylphthalate (DMP)	4 / 28	0.230 - 0.860	NA
* bis(2-Ethylhexyl)phthalate (B2EHP)	6 / 28	0.520 - 2.46	NA
Inorganic Chemicals:			
* Ammonia (NH3)	28 / 30	13.3 - 252	NA
* Antimony (SB)	27 / 30	2 - 6	2.5 - 4.0 (e)
Arsenic [Total] (AS)	30 / 30	1.9 - 41.5	14 - 46
Arsenic III (ASIII)	26 / 26	1.9 - 13.2	NA
Arsenic V (ASV)	23 / 23	0.6 - 24.2	NA
* Beryllium (BE)	12 / 30	1 - 1.6	NA
* Boron (B)	30 / 30	0.73 - 19.7	NA
Cadmium (CD)	1 / 30	2.2	0.005 - 1.1
Calcium (CA)	30 / 30	393 - 3,130	NA
Chromium (CR)	30 / 30	5.4 - 39.4	50 - 69
* Copper (CU)	30 / 30	6.5 - 66.7	41 - 45
Iron (FE)	30 / 30	2,190 - 40,400	40,000 - 45,000
Lead (PB)	26 / 30	10.3 - 47.9	42 - 66
Magnesium (MG)	30 / 30	943 - 5,650	NA
Manganese (MN)	30 / 30	63.3 - 379	1,000 - 3,400
* Mercury (HG)	26 / 30	0.2 - 2.55	0.1 - 0.3
Nickel (NI)	30 / 30	6 - 37.5	37 - 57
* Nitrite (NO2)	24 / 25	0.9 - 14.15	NA
Nitrogen (N2KJEL) (g)	30 / 30	84 - 5,800	NA
Phosphorous (P4)	22 / 27	5 - 340	NA
Potassium (K)	30 / 30	362 - 2,800	NA
Selenium (SE)	11 / 30	0.25 - 0.48	0.92 - 1.3 (e)
Sodium (NA)	30 / 30	677 - 4,530	NA
* Thallium (TL)	25 / 30	1 - 5.3	NA
* Zinc (ZN)	30 / 30	40.2 - 394	200 - 220

See footnotes on the following page.

TABLE 5-10 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SEDIMENT AT O-FIELD

(Concentrations reported in mg/kg)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations	Background Concentration (c)
GUNPOWDER RIVER (h)			
Inorganic Chemicals:			
* Ammonia (NH3)	3 / 4	5.6 - 56.0	NA
Antimony (SB)	1 / 4	2	2.5 - 4.0 (e)
Arsenic [Total] (AS)	4 / 4	1.6 - 1.9	14 - 46
Arsenic V (ASV)	4 / 4	1.6 - 1.9	NA
* Boron (B)	4 / 4	0.2 - 3.2	NA
Calcium (CA)	4 / 4	41 - 530	NA
Iron (FE)	4 / 4	1,490 - 2,770	40,000 - 45,000
Magnesium (MG)	4 / 4	77 - 550	NA
Manganese (MN)	4 / 4	31.4 - 191	1,000 - 3,400
* Nitrite (NO2)	3 / 4	1.15 - 1.40	NA
Nitrogen (N2KJEL) (g)	4 / 4	28 - 840	NA
Phosphorous (P4)	4 / 4	23 - 24	NA
Potassium (K)	4 / 4	78 - 227	NA
Sodium (NA)	4 / 4	209 - 1,390	NA
Zinc (ZN)	4 / 4	12.7 - 23.1	200 - 220

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Range of sediment concentrations reported for two monitoring stations in the Bush and Gunpowder Rivers, except as noted. Data derived from Maryland Chesapeake Bay Toxicant Monitoring Program. See text.
(d) Samples: 1 through 10, 13 through 20, 1S through 11S, and 20S.
(e) Range of concentrations in sediment reported for three stations located near the Chesapeake Bay Bridge and Annapolis. Data derived from NOAA (1988). See text.
(f) Value is for total carcinogenic and noncarcinogenic PAHs.
(g) Nitrogen as measured by Kjeldahl method.
(h) Samples: 24S through 27S.

NA = Not available.
* = Selected as a chemical of potential concern. See text.

detected in single samples, and butylbenzylphthalate was detected in two samples; these chemicals were detected at concentrations much lower than 1 mg/kg, and were therefore not selected as chemicals of potential concern for Watson Creek sediment. No organic chemicals were detected in Gunpowder River sediments.

Of the inorganic chemicals detected in Watson Creek, only antimony, copper, mercury, and zinc were estimated to be above background concentrations and were selected as chemicals of potential concern for the creek. No background data were available for ammonia, beryllium, boron, nitrite, and thallium, and therefore these chemicals were also selected as chemicals of potential concern for Watson Creek. Only ammonia, antimony, and nitrite were selected as chemicals of potential concern for the Gunpowder River (as a default position, because no background data were available with which to evaluate their site-relatedness).

Several TICs were detected in Watson Creek and Gunpowder River sediments. Analytical data for these compounds are summarized in Table 5-11. Some of these chemicals, such as hexanedecanoic acid, tetradecanoic acid, and octadecanoic acid are constituents of napalm, which was used at O-Field. These fatty acids would be expected to biodegrade in the environment. None of these chemicals was selected as a chemical of potential concern.

5.2.5 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Table 5-12 summarizes the chemicals of potential concern for each of the media sampled at O-Field. The available sampling data indicate that groundwater, surface water, and sediment are highly contaminated. VOCs and inorganic chemicals (principally metals) are the predominant chemicals of potential concern in groundwater and surface water, whereas PAHs, phthalates, and metals are the predominant chemicals of potential concern in sediment. Most of the chemicals of potential concern in groundwater are limited to shallow groundwater. These mobile chemicals may be discharging to surface water. Deep groundwater contains elevated levels of inorganic chemicals only.

The other chemicals of potential concern at O-Field are TNT, 1,3-dinitro-benzene, thiodiglycol, 1,4-dithiane, and methylphosphonic acid. Thiodiglycol and 1,4-dithiane, which are degradation products of mustard, are widespread contaminants in the shallow groundwater at Old O-Field. Methylphosphonic acid, a hydrolysis product of VX and GB, was detected in single groundwater samples from both Old and New O-Field. TNT and 1,3-dinitrobenzene were detected in one and two samples, respectively.

In addition to the chemicals of potential concern selected for each medium using the available sampling data, other chemicals are likely to be present at O-Field and may be of potential concern with respect to possible exposures and impacts. Table 5-13 summarizes additional chemicals of concern potentially present at O-Field that either (1) were not included in any of the chemical analyses (e.g., DIMP, lewisite oxide); (2) were included, but were analyzed for only once and/or with high detection limits (e.g., munitions compounds, IMPA); or (3) were not analyzed for or were analyzed for infrequently in specific media (e.g., thiodiglycol in surface water). The chemicals listed have the potential to be present in the greatest quantities based on historical information. A large number of other chemicals could be present in smaller quantities at O-Field and therefore also could contribute to potential exposures and risks. For example, degradation products of adamsite, a-chloroacetophenone, CS, and chloropicrin are possibly present in groundwater at Old O-Field but probably at lower concentrations, given that smaller quantities of the parent compounds are believed to have been disposed of at O-Field.

TABLE 5-11

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN OLD O-FIELD SEDIMENTS

(Concentrations reported in mg/kg)

Chemical	Number of Detects (a)	Range of Reported Concentrations (c)
Watson Creek (b)		
Bicyclohexyl	1	0.06
Hexadecanal	1	0.61
Hexanedecanoic Acid	1	1.5
Hexathiepene	1	0.28
4-Hydroxy-3-methoxy Benzaldehyde	2	0.17 - 0.25
Propanoic Acid, 2-methyl-3-hydroxy-2,4,4-trimethyl Pentylester	1	0.1
Sulfur	5	0.26 - 31
Gunpowder River (c)		
1,1-Biphenyl-2-ol	1	0.015
Substituted Naphthalene	1	0.325
Substituted Naphthalenol	1	0.211
Tetradecanoic Acid	1	0.255
Sulfur	1	32
Octadecanoic Acid	1	0.232

(a) Number of samples in which the chemical was tentatively identified.
(b) Samples: 1, 2, 3S, 4, 4S, 5S, 6, 6S, 7, 7S, 8, 9S, 10, 14, 16, 17, 19, and 20.
(c) Samples: 24S, 25S, 26S, and 27S.

TABLE 5-12

SUMMARY OF CHEMICALS OF POTENITAL CONCERN FOR O-FIELD

Chemical (a)	Soil	Groundwater Old O-Field (b)	 New O-Field	Surface Water Watson Creek	 Gunpowder River	Sediment Watson Creek	 Gunpowder River
Organic Chemicals:							
Benzene (C6H6)		X	X	X			
Carbon Tetrachloride (CCL4)		X		X			
Chlorobenzene (CLC6H5)		X	X				
Chloroform (CHCL3)		X	X	X			
1,2-Dichloroethane (12DCLE)		X	X	X			
1,1-Dichloroethene (11DCE)		X		X			
1,2-Dichloroethene (12DCE)		X	X	X			
1,3-Dinitrobenzene (13DNB)		X					
1,4-Dithiane (DITH)							
Ethyl Benzene (ETC6H5)		X		X			
Methylene Chloride (CH2CL2)		X	X				
Methylphosphonic Acid (MPA)		X	X				
PAHs [carcinogenic]						X	
PAHs [noncarcinogenic]						X	
Phthalates:							
Di-n-butylphthalate (DNBP)						X	
Di-ethylphthalate (DEP)						X	
Dimethylphthalate (DMP)						X	
Di-n-octylphthalate (DNOP)				X			
bis(2-Ethylhexyl)phthalate (B2EHP)					X	X	
1,1,2,2-Tetrachloroethane (TCLEA)		X	X	X			
Tetrachloroethene (TCLEE)		X	X				
Thiodiglycol (TDGCL)		X					
Toluene (MEC6H5)		X	X				
1,1,2-Trichloroethane (112TCE)		X	X				
Trichloroethene (TRCLE)		X	X	X			
[illegible]4,6-Trinitrotoluene (246TNT)		X					
[illegible]nyl Chloride (C2H3CL)		X	X	X			
Inorganic Chemicals:							
Ammonia (NH3)						X	X
Antimony (SB)		X (X)		X	X	X	
Arsenic (AS)	X	X (X)		X	X		
Beryllium (BE)						X	
Boron (B)		X		X	X	X	X
Cadmium (CA)				X			
Copper (CU)				X		X	
Fluoride (F)		X		X			
Iron (FE)		X		X			
Manganese (MN)		X		X	X		
Mercury (HG)				X		X	
Nitrite (NO2)						X	X
Selenium (SE)				X	X		
Sulfate (SO4)		(X)		X	X		
Sulfide (SULFID)		X (X)					
Thallium (TL)						X	
Zinc (ZN)		X (X)		X		X	
Radiological Parameters:							
Gross Beta (BETAG)		X					

(a) USATHAMA chemical codes listed in parentheses.
(b) Chemicals of potential concern for shallow groundwater are designated by X and those for deep groundwater are designated by (X).

X = Selected as a chemical of potential concern.

NOTE: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium, (2) it was not included in the analyses, or (3) it was detected at background concentrations (inorganic chemicals only). See text for this information.

TABLE 5-13

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT
O-FIELD (a)

Group	Chemical	Comments
Lethal Chemical Agents	Mustard (H or HD) Lewisite (L) Phosgene (CG) Cyanogen Chloride (CK) Hydrogen Cyanide (AC) Tabun (GA) Sarin (GB) VX	Several of these compounds were analyzed for in groundwater but not in other media. Historical information indicates that large quantities of H/HD and L were disposed at Old O-Field in munitions and in bulk form. Therefore, both H/HD and L could be present in buried munitions. Mustard also could persist in bulk form in subsurface environments but lewisite is unlikely to do so. CG, AC, and CK could be present in artillery rounds buried at the site. Laboratory quantities of nerve agent also were allegedly disposed at Old O-Field, as were captured munitions containing nerve agents. Nerve agents could exist in munitions in subsurface soils. In addition, GA and VX could persist in subsurface soil outside of munitions.
Incapacitating Agents	Adamsite (DM) CN CS PS	These chemicals were not analyzed for in any medium at O-Field. Drums containing adamsite were allegedly buried at Old O-Field, along with tear agents, which may have been contained in drums or in munitions. DM, CN, CS and PS are all relatively persistent in the environment (particularly when disposed in bulk form) due to either a slow rate of solution, low solubility or slow hydrolysis. Therefore, each of these compounds may be present in subsurface environments at Old O-Field in drums, munitions or soil.
Agent Breakdown Products	Thiodiglycol 1,4-Dithiane Methylphosphonic Acid (MPA)	These chemicals are agent breakdown products and have been detected frequently and/or at high concentrations in shallow groundwater at O-Field, including wells located nearest to Watson Creek, where groundwater discharges. These chemicals were not analyzed for in surface water but could be present in Watson Creek surface water as a result of groundwater discharge.
	Lewisite Oxide Chlorovinylarsonic Acid	These compounds are degradation products of lewisite. Lewisite oxide, which could be present and mobile in groundwater, was not analyzed for at O-Field. Chlorovinylarsonic acid (an oxidation product of lewisite oxide) was analyzed once in groundwater (and not detected). Both compounds could be present in surface water, but were not analyzed for in this medium.
	Ethylmethylphosphonic Acid (EMPA) Isopropylmethylphosphonic Acid (IMPA) Di-isopropylmethyl Phosphonate (DIMP) Pinacolylmethylphosphonic Acid	The compounds are all nerve agent degradation products. All but DIMP have been analyzed for in groundwater, but with high detection limits. They could exist in groundwater and also could be discharged with groundwater to surface water.
	1,4-Thioxane Thiobenzoic Acid Thiophene Diphenyl Sulfide Diphenyl Sulfoxide 5-Methyl Thiobenzoate	These compounds were not analyzed for at O-Field, but all are possible thermal degradation products of mustard. They could be present in groundwater and/or in soil at potentially large quantities given the large quantities of mustard reportedly disposed at Old O-Field and past burning that took place during demilitarization actions. If present in groundwater, they also could be released to surface water.

See footnote on the following page.

TABLE 5-13 (Continued)

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT O-FIELD (a)

Group	Chemical	Comments
Munitions Compounds	TNT 2,4-DNT 2,6-DNT HMX RDX 1,3,5-TNB 1,3-DNB Nitrobenzene Tetryl	These chemicals were analyzed for only once or twice in groundwater. Only TNT and 1,3-DNB were detected, but all could be present. If present in groundwater, all these chemicals could be discharging to surface water. Surface water samples were not analyzed for these compounds.
Incendiary Materials	White Phosphorus (WP) Plasticized WP (PWP) FS	WP/PWP were reportedly disposed at Old O-Field along with drums of FS. All three compounds could be present in raw form in the subsurface environment (principally in soil and sediment).
Miscellaneous	Ammonia	Ammonia was measured at elevated levels in groundwater but was analyzed for only once at two sample locations in surface water. Given the high concentrations in groundwater it could be present in surface water.

(a) Based on historical information. Chemicals listed are those potentially present in the greatest quantities. A large number of other chemicals could be present in smaller quantities at O-Field.

Lethal chemical agents, incapacitating agents, and incendiary materials are of potential concern at O-Field primarily because of the potential for a fire or explosion and the release and dispersion of agents into the atmosphere. Agent breakdown products (along with some of their parent compounds), munition compounds, and ammonia are of concern because of their potential contribution to groundwater, soil, and/or surface water contamination.

5.3 HUMAN HEALTH RISK ASSESSMENT

This section addresses the potential human health risks associated with the O-Field study area in the absence of remedial actions. This human health risk assessment is divided into three principal sections. Section 5.3.1 evaluates and provides estimates of potential human exposures for the chemicals of potential concern at the site, Section 5.3.2 summarizes relevant toxicity information for the chemicals of potential concern, and Section 5.3.3 provides quantitative and qualitative estimates of human health risks.

5.3.1 EXPOSURE ASSESSMENT

This section identifies the pathways by which human populations may be exposed to chemicals of potential concern at or originating from O-Field and presents the pathways selected for further evaluation. Only complete pathways were selected for further evaluation (see Chapter 4 for a definition of a complete pathway). Evaluations of exposures may be quantitative or qualitative depending upon several factors, including the probability of exposure, the potential magnitude of exposure, and the availability of data to support quantitative evaluations. Exposure point concentrations and daily intakes were estimated for pathways selected for quantitative evaluation.

This exposure assessment is organized into three principal sections. Section 5.3.1.1 discusses potential exposure pathways under current land-use conditions, and Section 5.3.1.2 discusses those potentially occurring under hypothetical future land-use conditions. Section 5.3.1.3 presents estimates of potential human exposures for those pathways selected for quantitative evaluation.

5.3.1.1 Potential Exposure Pathways Under Current Land-Use Conditions

Access to Old O-Field is very restricted. Institutional and access restrictions are in place at the site. Activity within the site is banned by order of the APG Commanding Officer. The O-Field area is located within a restricted section of the installation. Entry to this area is strictly controlled. The restricted area is subject to patrols by MPs and other armed security forces. In addition a wide variety of additional physical security countermeasures are employed to preclude unauthorized entry to this area. Protective clothing and a technical escort are required for anyone entering within the fenced area of Old O-Field. Protective measures for entering New O-Field are less extensive; technical escort is required, but protective clothing is not. Access to areas within the fenced area of Old O-Field is permitted only under limited circumstances.

The majority of the land surrounding O-Field is used as testing ranges. H-Field, which is used primarily for smoke testing operations, is located approximately 4,800 feet south of O-Field. H-Field is used approximately 80% of the workdays during the year and on occasional weekends.[1] A tank testing track is located along the northern boundary of H-Field. South of the tank testing track there are several offices for semi-permanent and short-term use. M-Field, which is located 3,800 feet northeast of O-Field across Watson Creek, is a frequently used range field. M-Field is used daily by permanent personnel and intermittently by other personnel.[2] P-Field, which is located east of O-Field, is not used. In general, personnel on Gunpowder Neck are not equipped with gas masks, although gas masks may be required during certain testing activities.[3]

The closest water supply wells are located in H-Field, which is upgradient of O-Field. There are two wells in H-Field south of Building 1464. Water from these wells was tested several years ago and found to have low-level volatile organic contamination. As a result, water from these wells currently is used only for nonpotable uses (e.g., vehicle washing, showering). There are no water supply wells downgradient of O-Field.

Hunting and trapping are not allowed at O-Field, but do occur south of O-Field, in H-Field. Game species at H-Field are upland game/early migratory birds, migratory game birds, turkey, deer, and woodchuck. Fishing occurs in the Gunpowder River, west of O-Field. There are no areas in the O-Field study area that are approved for recreational fishing or crabbing from the shoreline.

The industrial sector of the Edgewood Area of APG is located 3.5 miles north of O-Field. This area also houses military personnel on assignment to APG. Within 5 miles of O-Field, to the north, are the towns of Edgewood and Magnolia (off-post). The closest off-post housing development is located in Graces Quarters, approximately 2.5 miles due west across the Gunpowder River.

The following section discusses potential long-term exposure pathways under current land-use conditions.

5.3.1.1.1 Potential Long-term Exposure Pathways Under Current Land-Use Conditions

Table 5-14 summarizes the pathways by which humans could be exposed to chemicals at or originating from O-Field. Potential exposure pathways are discussed below by exposure medium.

Surface Soil. Exposure to chemicals in surface soil could occur via dermal contact and/or incidental ingestion. (Inhalation exposures to chemicals that are present on wind-blown dust or that volatilize from soil are discussed under the section on air.) No monitoring data are available on the levels of chemicals present in surface soils at O-Field. However, given past disposal activities, surface contamination is likely. Chemical concentrations are likely to be greatest in and near the disposal

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[1] Ibid.

[2] Ibid.

[3] Ibid.

TABLE 5-14

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT O-FIELD

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Soil/ Old O-Field	Dermal contact and/or incidental ingestion of soil by Tec Escort and other personnel occasionally working at O-Field.	Negligible. Access to O-Field is severely restricted. Further, protective clothing must be worn by anyone entering within the fenced area of Old O-Field.	NA. Data not collected.	None, due to low potential for exposure and lack of data.
Surface Soil/ New O-Field	Dermal contact and/or incidental ingestion of soil by Tec Escort staff using temporary offices at New O-Field.	Negligible. Probable area of contamination (disposal pits) is not frequented by Tec Escort personnel. Infrequent exposure to low-level contamination possibly present in office areas is likely to result in insignificant exposures.	NA. Data not collected.	None, due to low potential for exposure and lack of data.
Subsurface Soil	None. Although subsurface soils are likely to be contaminated as a result of past waste disposal, no activities that involve potential contact with subsurface soil (e.g., excavation) take place at O-Field.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Groundwater	None. Although chemical transport to groundwater from sources has occurred, there are no human uses of groundwater at the site or in downgradient areas.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Surface Water/ Sediment	None. Although chemicals in groundwater are discharging to surface water, the limited activities at O-Field do not involve contact with surface water or sediment. Nearby surface waters are not used as a source of drinking water nor are they used for swimming.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Fish	Ingestion by local fishermen of fish that have accumulated chemicals from Watson Creek or the Gunpowder River near O-Field.	Negligible. Some chemicals detected in Watson Creek could accumulate in fish. However, significant accumulation is not likely given the larger foraging areas and habitat preferences of the types of fish likely to be caught in the Gunpowder River and eaten.	Poor. No fish tissue data available for fish in Gunpowder River. Data from fish in Watson Creek inadequate and inappropriate for calculating potential exposures for fishermen in the Gunpowder River.	None, due to low potential for exposure.

See footnotes on the following page.

TABLE 5-14 (Continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT O-FIELD

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Game	Ingestion of game that has accumulated chemicals from O-Field by persons hunting at H-Field.	Negligible. None of the chemicals detected at O-Field bioaccumulates extensively in terrestrial wildlife.	Poor. No tissue samples available and no information on surface soil contamination.	None, due to low potential for exposure.
Air	Inhalation by workers of vapors that have volatilized from Watson Creek surface water and from soil at O-Field.	Moderate. Volatile chemicals are present in groundwater and groundwater is known to discharge to Watson Creek. Volatile chemicals in groundwater also could be transported to air via migration through soil. Further, there is daily and intermittent use of nearby areas by workers.	Poor. No air data available. Too few surface water samples collected from Watson Creek to give an accurate representation of water concentrations.	Quantitative with a high degree of uncertainty.
Air	Inhalation by workers of dust that has eroded from surface soil at O-Field.	Negligible. Dust generation and transport is unlikely because the area is vegetated, sheltered from high winds by surrounding forests and likely has a high soil moisture content.	NA. Data not collected.	None, due to low potential for exposure.
Air	Acute hazards: fire or explosion at O-Field with subsequent dermal and inhalation exposures for individuals working nearby and for on-post and off-post residents.	**INFORMATION IN THIS TABLE REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."**		

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.
NA = Not applicable.

pits/trenches of both Old and New O-Field. However, lower-level contamination could occur throughout O-Field as a result of particle deposition during past fires or explosions or as a result of previous demilitarization activities that involved surface burning and application of fuel oil.

The potential for direct contact exposures with soil by humans at Old O-Field is small at the present time. Potential hazards associated with the site are well known, and access to the field is severely restricted by direct order of the Tec Escort commanding officer, the commander of APG, and the Chemical Surety Office. The only personnel potentially exposed via direct contact at the present time are Tec Escort personnel. However, because protective clothing is required for anyone entering within the fenced area of Old O-Field, direct contact exposures are unlikely to occur under current-use conditions.

Direct contact exposures are potentially more likely at New O-Field, given that protective clothing is not required and that Tec Escort staff occasionally use the offices located at New O-Field. However, it is unlikely that the soils near the offices are significantly contaminated, as the offices are located approximately 400 feet southwest of the pits/trenches at New O-Field where disposal activities occurred, and that surface drainage runs from the pit/trench area towards Watson Creek and away from the on-site buildings. Low-level surface contamination could exist near the office buildings as a result of "tracking" by vehicles that hauled wastes to the pit/trench area in the past, or as a result of surface deposition from explosions or fires that occurred at Old O-Field. Contaminated dust within the offices also is possible, but not likely to be significant given that dust transport from contaminated areas is probably negligible (see below under air). Even if chemicals were present in surface soil near the on-site buildings or in dust in the buildings, the concentrations would probably be so low and exposure would be so infrequent (approximately 30 days/year), the resulting exposure would be likely to be negligible.

Because of the low potential for significant exposures, no direct contact soil pathways were selected for evaluation at O-Field for current land-use conditions.

Subsurface Soil. Exposure to chemicals in subsurface soil could occur via dermal contact and/or incidental ingestion during activities such as excavation. Limited monitoring data are available on the levels of chemicals in subsurface soils, but the potential for significant contamination exists. Because no activity that involves contact with subsurface soils occurs at O-Field however, no complete exposure pathway exists under current land-use conditions.

Groundwater. There are no human uses of groundwater from the site or in downgradient areas. Therefore, no complete groundwater exposure pathways exist under current land-use conditions.

Surface Water/Sediment. Direct human exposure to chemicals in O-Field surface waters/sediments is not likely under current land-use conditions. Nearby surface waters are brackish (salinity ~1 ppt) and are not used as a source of potable water. People do not swim in the Gunpowder River near O-Field and are unlikely to contact chemicals in surface water or sediment while fishing in the river. There is no human contact with Watson Creek surface waters/sediment during the restricted activities that occur at O-Field. Therefore, direct contact and direct ingestion exposures to chemicals in surface water/sediment is not likely under current land-use conditions, and the pathway was not selected for evaluation.

Fish. It is possible that people consuming fish caught in the Gunpowder River could be exposed to chemicals that have accumulated from surface water or sediment. Of the chemicals of potential concern in O-Field surface water and sediment, mercury has the potential to bioaccumulate to the greatest extent in fish. Mercury was detected at elevated levels in the surface water and sediment of Watson Creek, but appeared to be within background levels in Gunpowder River surface water; it was not detected in Gunpowder River sediments. Given this distribution, if mercury bioaccumulation is occurring, it is likely to be greatest in fish that spend all of their time in Watson Creek, and less in fish that spend no time or only a portion of their time in Watson Creek and the remaining time in areas not contaminated with mercury (e.g., Gunpowder River).

Assuming that the contaminated area and the surrounding area provide equally suitable habitat for a particular fish species, the amount of time a given fish spends in a contaminated area depends upon the size of the contaminated area and the size of the fish's foraging or home range area. Because many of the fish species of commercial and recreational importance at APG tend to be larger species (e.g., white perch, channel catfish) that are likely to forage over large areas, they are unlikely to spend all of their time in one area, such as Watson Creek. Furthermore, some of these commercial/recreational fish species (e.g., striped bass) are less likely to spend significant portions of their time in Watson Creek, because it does not provide preferred habitat (see species profiles in Appendix D). The fish species with the greatest potential to accumulate significant amounts of mercury from Watson Creek are smaller species, which are residents of Watson Creek (e.g., mummichog, killifish, silverside). However, these species are not caught or consumed by commercial or recreational fishermen.

It is difficult to predict potential bioaccumulation in fish species when the contaminated area is an "open system" and fish can move in and out of a contaminated area. Typically, bioaccumulation in fish is estimated using simple models (i.e., using bioconcentration factors) that assume continuous exposure of the fish to a constant chemical concentration and equilibrium partitioning of a chemical between the fish (or fish tissue) and water. However, such conditions would not occur in situations where fish can move in and out of the contaminated area, as is the case for the commercial/recreational fish species in the O-Field area. Therefore, partitioning models typically used to evaluate bioaccumulation are not appropriate.

Despite the lack of appropriate models or sufficient data to evaluate this potential pathway, evidence suggests the commercial/recreational fish species in the O-Field area are unlikely to spend significant portions of their time in Watson Creek. It is therefore unlikely that people fishing in the Gunpowder River would catch and consume fish that have accumulated significant quantities of mercury from Watson Creek. The potential magnitude of exposure for this pathway is probably low. The two fish tissue residue studies (AEHA 1985, 1978) that have been conducted in Watson Creek to date are inconclusive due to: (1) variations in the detection limits between the studies; (2) differences in the species collected; (3) a lack of information on the age, size, and weight of the fish collected; (4) information on the tissues analyzed (1978 study only); and (5) information on wet weight or dry weight concentrations (1985 study only). Nevertheless, based on the reasoning outlined above, accumulation of mercury from Watson Creek by fish is not expected to result in significant exposures to persons fishing in the Gunpowder River, and this pathway was not selected for further evaluation.

Game. No hunting is allowed at O-Field, but it is allowed in H-Field directly south of O-Field. Conceivably, deer, waterfowl, and other game animals could be exposed to chemicals present at O-Field (e.g., via drinking water, ingestion of food) and be killed and consumed by individuals hunting at H-Field. None of the chemicals detected at O-Field tend to accumulate significantly in terrestrial species, however; potential accumulation in terrestrial food chains is generally associated with nonpolar, fat-soluble chemicals such as PCBs or dioxins. Metals and soluble organic chemicals, such as those detected in the surface waters in Watson Creek, do not accumulate significantly in terrestrial food chains. For this reason and because game hunted at H-Field would only spend a small portion of its total foraging time at O-Field, significant exposures via the ingestion of game that has accumulated chemicals from O-Field is unlikely. Therefore, this pathway was not selected for evaluation.

Air. Air contamination at O-Field can result from direct volatilization of chemicals and transport by wind entrainment of chemicals present on dust particles. (Atmospheric dispersal of contaminants as a result of an explosion or fire is discussed in the section on acute exposures.) Migration of contaminants by wind entrainment of dust particles is unlikely to be an important transport process at O-Field because the area is completely vegetated and somewhat sheltered from high winds by surrounding forests, and the soil is likely to have a high moisture content for all or most of the year.

Transport through volatilization is more likely. Release of volatile chemicals to the atmosphere at O-Field can occur as a result of groundwater discharge to surface water with subsequent volatilization or as a result of volatilization in subsurface environments (from groundwater, soils or wastes) and transport through soil spaces to the atmosphere. Groundwater containing VOCs is known to be discharging to Watson Creek, and this probably is an important source of volatile emissions at O-Field. Subsurface transport from wastes, subsurface soils, and groundwater could contribute significantly to overall emissions given the potential for significant subsurface contamination at O-Field. However, no data are available with which to evaluate this migration pathway, and therefore, this pathway was not selected for evaluation.

Chemicals volatilizing from surface water could reach potential receptors via atmospheric dispersion from the emission source to potential receptor locations, resulting in inhalation exposures. At the present time, the only persons who spend an appreciable amount of time near O-Field are APG personnel involved in testing activities at H-Field or in range activities at M-Field. Tec Escort personnel occasionally use the offices located at New O-Field and also could be exposed to volatile chemicals. Because volatile chemicals are known to be discharging to surface water and atmospheric transport is likely, this exposure pathway was selected for quantitative evaluation. Exposures for workers at H-Field, M-Field, and New O-Field were evaluated.

5.3.1.1.2 Potential Acute Exposures Under Current Land-Use Conditions

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

5.3.1.2 Potential Exposure Pathways Under Future Land-Use Conditions

It is possible, although unlikely, that use restrictions at O-Field could be lifted in the future. The most likely alternate use of O-Field would be as a test range, explosive ordnance disposal area, or training area. Other uses of the area (e.g., as a commercial or industrial area) are unlikely given that O-Field is located in a test range area and that there is the possibility that unexploded ordnance is present in the area. If use restrictions were lifted in the future, workers at O-Field could be exposed to chemicals in surface soil via direct contact and incidental ingestion and to chemicals in air via inhalation. Exposures to chemicals in subsurface soils and groundwater are not considered likely under any reasonable future-use scenario. Excavation of subsurface soils for other than remedial purposes is highly unlikely given the known hazards that exist at O-Field. Use of groundwater as potable or nonpotable water is not considered plausible given the absence of existing wells and the institutional controls at APG, as well as the institutional knowledge of the contaminated nature of the groundwater at O-Field.

It is unlikely that human use of Watson Creek will change in the future. It is conceivable, although unlikely, that in the future the Gunpowder River near O-Field could be used for swimming. Persons swimming in the Gunpowder River could be directly exposed to chemicals in surface water via dermal absorption and via incidental ingestion of surface water.

The exposure pathways potentially occurring at O-Field in the future are summarized in Table 5-15. These pathways were selected for qualitative evaluation only, because of their low probability of occurring in the future.

5.3.1.3 Quantification of Exposure

In this section, the exposure pathway selected for quantitative evaluation, chronic inhalation exposures to chemicals that have volatilized from Watson Creek surface water, is presented. Chronic inhalation exposures to volatilized chemicals were evaluated for workers at H-Field, M-Field, and New O-Field.

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

The methods used to evaluate these exposures are described below.

TABLE 5-15

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER HYPOTHETICAL FUTURE LAND-USE CONDITIONS AT O-FIELD

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposures (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Soil	Dermal contact and/or incidental ingestion of soil by workers.	Negligible to high. High if use changes in the future. Although surface soil samples have not been collected in this area, surface contamination is likely, particularly in Old O-Field, given past disposal and demilitarization activities. However, it is considered highly unlikely that use restrictions would be lifted in the future.	Poor. No surface soil data collected.	Qualitative, due to lack of data and small likelihood that use will change in the future.
Surface Water	Dermal contact and incidental ingestion by persons swimming in the Gunpowder River.	Negligible to moderate. The principal chemicals in Gunpowder River surface water are metals, which are not dermally absorbed to any appreciable extent. Exposures could occur through incidental ingestion. However, it is considered unlikely that the Gunpowder River near O-Field would be used in the future for swimming.	Poor. Samples collected from only three locations in the Gunpowder River near O-Field.	Qualitative, due to limited data and small likelihood that use will change in the future.
Air	Inhalation of chemicals that have volatilized from Watson Creek surface water and from soil by workers at Old O-Field.	Negligible to high. Volatile chemicals are present in groundwater which is being released to Watson Creek. Volatilization through soil also could be occurring. However, it is considered unlikely that use restrictions would be lifted at O-Field.	Poor. No air data available. Available surface water data not adequate to characterize concentrations in Watson Creek, where principal emissions would be generated.	Qualitative, due to small likelihood that use will change in the future.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.

5.3.1.3.1 Chronic Inhalation Exposures to Chemicals That Have Volatilized From Surface Water

Chronic inhalation exposures were evaluated by calculating chronic daily intakes (CDIs) for the potentially exposed populations. Exposure point concentrations were first calculated, and then intakes were estimated using assumptions regarding the magnitude, frequency, and duration of exposure.

Estimation of Exposure Point Concentrations. No air samples for VOCs were collected as part of the USGS study or other investigations at O-Field, making it impossible to assess directly this potential exposure scenario. Therefore, exposure point concentrations are estimated using models that account for volatilization from surface water and atmospheric dispersion to receptor points.

Volatile emissions from Watson Creek were estimated using the Liss and Slater (1974) surface water volatilization model. This model is based on a kinetic mass transfer approach, in which mass transfer coefficients are calculated on a chemical-specific basis and used along with surface water physical parameters to estimate volatilization rates to the atmosphere. As input to this model, representative concentrations of volatile chemicals in surface water are needed. As discussed previously, groundwater discharge is the source of volatile chemicals in Watson Creek. Groundwater discharge to Watson Creek is not continuous; it is more periodic, being somewhat tidally influenced. This tidal effect results in a pulse-type release of contaminated groundwater to the creek. As a result, chemicals released to surface water can be dispersed within surface water and volatilize before the next slug of groundwater discharges to the creek. Because of the dynamic nature of groundwater/surface water interactions at O-Field, it is not appropriate to use measured surface water concentrations obtained from one or a few sampling episodes to model volatile releases. Therefore, for this assessment, average surface water chemical concentrations between groundwater discharge events were estimated as input to the Liss and Slater model.

Average surface water concentrations between groundwater discharge events were calculated by using measured concentrations in the shallow groundwater and (1) estimating the volume of groundwater that discharges to the creek and the initial surface water concentrations that result after dilution of the discharge within the creek and then (2) integrating volatilization loss over time between discharge periods. The specifics of this approach are described briefly below. A complete description of the methods and assumptions used to model average surface water concentrations is presented in Appendix A.

Chemical concentrations in groundwater at the discharge point were assumed to be represented by the levels measured in monitoring wells located closest to the Watson Creek shoreline (i.e., the discharge area). This approach is consistent with the findings of Vroblesky et al. (1990), which indicated that the concentrations of VOCs in Watson Creek at the groundwater discharge point corresponded closely to those detected in the nearest wells. The arithmetic mean chemical concentrations for these wells were presented previously in Table 5-4.

The contaminated groundwater discharge rate (Q) to Watson Creek was estimated from information from Vroblesky et al. (1990) on hydraulic conductivity, hydraulic gradient, and the cross-sectional area of plume discharge in the creek. Lower-bound and upper-bound estimates of Q were derived based on variations in the size of the plume discharge area (see Vroblesky et al. 1990). For the purpose of this analysis, Q was calculated to represent the volume of groundwater that enters the creek each day (i.e., a daily discharge volume, or "discharge event").

Initial surface water concentrations, resulting from dilution of the contaminated groundwater in the surface water body but not accounting for any other processes (i.e., volatilization), were estimated using a standard mass balance approach:

$$C_3 = (C_1V_1 + C_2V_2)/(V_1 + V_2) \qquad \text{(Eq. 1)}$$

where

C_3 = chemical concentration in surface water as a result of groundwater discharge;

C_1 = chemical concentration in groundwater;

C_2 = background chemical concentration in surface water;

V_1 = daily groundwater discharge volume; and

V_2 = creek dilution volume.

For the purpose of this assessment, lower-bound and upper-bound dilution volumes were used for the creek dilution volume (V_2) to account for uncertainty regarding the discharge area and likely initial mixing volume of surface water. In addition, the background chemical concentration (C_2) was assumed to be zero for all VOCs, under the assumption that volatilization and dilution between discharge events would be sufficient to result in negligible residual concentrations in surface water (this assumption is consistent with measured levels of VOCs in Watson Creek, which are generally quite low). A "low estimate" of initial surface water concentrations (i.e., based on a minimum groundwater discharge volume and a maximum surface water dilution volume) and a "high estimate" of initial surface water concentrations (i.e., based on a maximum groundwater discharge volume and a minimum surface water dilution volume) were generated and are presented in Table 5-16.

Based on these estimated initial surface water concentrations, average surface water concentrations between discharge events are estimated by integrating volatilization loss over time between discharge periods. Concentrations of volatile chemicals in surface water at any time between discharge periods is given by:

$$C(t) = C_o * e^{-k_v t} \qquad \text{(Eq. 2)}$$

where

$C(t)$ = concentration in the surface water at any time between discharge periods (μg/L);

C_o = initial surface water concentration (μg/L);

k_v = volatilization rate constant (hrs^{-1}); and

t = time after groundwater discharge (hrs).

The average surface water concentration between discharge periods is the integral of Eq. 2 divided by the time between groundwater discharge events as follows:

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TABLE 5-16

ESTIMATED CHEMICAL CONCENTRATIONS IN WATSON CREEK SURFACE WATER BASED ON MODELED GROUNDWATER DISCHARGE AND DILUTION WITHIN THE DISCHARGE ZONE IN WATSON CREEK

(Concentrations reported in ug/L)

Chemical (a)	Concentration in Groundwater (b)	Estimated Surface Water Concentrations			
		High Estimate (c)		Low Estimate (d)	
		Initial	Average	Initial	Average
Benzene (C6H6)	200	84	18.4	13	2.84
Carbon Tetrachloride (CCL4)	48	20	5.79	3	0.868
Chlorobenzene (CLC6H5)	42	18	4.78	3	0.797
Chloroform (CHCL3)	300	130	35.2	20	5.42
1,2-Dichloroethane (12DCLE)	190	80	22.6	13	3.67
1,2-Dichloroethene (12DCE)	600	250	59	40	9.44
1,3-Dinitrobenzene (13DNB)	24	10	10	2	2
1,4-Dithiane (DITH) (e)	150	63	NA	10	NA
Methylene Chloride (CH2CL2)	68	29	6.9	5	1.19
Methylphosphonic Acid (MPA)	1,600	670	NA	110	NA
1,1,2,2-Tetrachloroethane (TCLEA)	690	290	121	46	19.2
Tetrachloroethene (TCLEE)	94	39	11.7	6	1.79
Thiodiglycol (TDGCL)	31,000	13,000	NA	2,100	NA
Toluene (MEC6H5)	13	5	1.17	1	0.235
1,1,2-Trichloroethane (112TCE)	28	12	3.81	2	0.635
Trichloroethene (TRCLE)	530	220	60.2	35	9.58
Vinyl Chloride (C2H3CL)	200	84	15.8	13	2.45

(a) USATHAMA chemical codes listed in parentheses.
(b) Arithmetic mean concentration in wells located closest to Watson Creek. Samples: 14A, 14B, 14C, 20A, 20B, 21, 22A, and 22B.
(c) Estimated concentration assuming maximum groundwater discharge and minimum surface water dilution volume.
(d) Estimated concentration assuming minimum groundwater discharge and maximum surface water dilution volume.
(e) Samples: 14A, 14B, 14C, 21, and 22.

NA = Not applicable. Chemical is relatively non-volatile.

$$C_{avg} = \frac{1}{t}\int_{0}^{t} C_o e^{-k_v t} dt \qquad \text{(Eq. 3)}$$

where

C_{avg} = average surface water concentration between groundwater discharge events (μg/L);

C_o = initial surface water concentration (μg/L);

k_v = volatilization rate constant (hrs^{-1}); and

t = time between discharge events (24 hrs).

These concentrations were input to the Liss and Slater (1974) surface water volatilization model to calculate chemical-specific flux rates. The product of the chemical-specific flux rates and the area over which volatilization occurs yields chemical-specific emission rates.

After emission rates were predicted they were linked to the Industrial Source Complex Long Term (ISCLT) air dispersion model (EPA 1987a) to predict ambient air concentrations at each of three selected receptor locations. The resulting exposure point concentrations for workers at H-Field, M-Field, and New O-Field are presented in Table 5-17. Air concentrations were not calculated for thiodiglycol, methylphosphonic acid, and 1,4-dithiane (even though these compounds were present in the plume and initial surface water concentrations were estimated for them) because of their relative nonvolatility. The complete air emission and air dispersion modeling is discussed in detail in Appendix A.

<u>Estimation of Intakes</u>. Inhalation CDIs are calculated for the selected receptors using the estimated exposure point concentrations presented in Table 5-17 and the exposure parameters presented in Table 5-18 and discussed below. In all cases, absorption of the inhaled chemical is assumed to be equal to that which occurred in the toxicity studies on which the inhalation RfD or inhalation cancer slope factor for a given chemical is based.

Workers are assumed to work a total of 241 days each year (5 days per week, 2 weeks vacation, 9 holidays). However, the total number of days a worker spends at a M-Field, H-Field, or New O-Field is assumed to vary.[5] Workers are assumed to be present at M-Field every work day (241 days/year) and at H-Field 80% of the work days each year (193 days/year). Workers are assumed to be present at New O-Field 30 days/year. All workers are assumed to work 8 hours/day at a given location and to work for a total of 20 years at APG. Further, workers are assumed to weigh 70 kg (EPA 1989a) and breathe at a rate of 2 m^3/hr, which is the mean ventilation rate for male and female adults engaged in moderate activity (EPA 1985a).

Using these assumptions, CDI estimates for worker inhalation exposures are calculated using the following equation:

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[5] Nemeth, G. 1990. Personal communication, AEHA.

TABLE 5-17

ESTIMATED EXPOSURE POINT CONCENTRATIONS FOR EVALUATION OF WORKER INHALATION EXPOSURES TO CHEMICALS VOLATILIZING FROM WATSON CREEK (a)

(Concentrations reported in mg/m3)

	Best Case (c)			Worst Case (d)		
Chemical (b)	H-Field	M-Field	New O-Field	H-Field	M-Field	New O-Field
Benzene (C6H6)	1.92E-06	1.36E-06	5.30E-06	6.15E-06	4.48E-06	1.68E-05
Carbon Tetrachloride (CCL4)	4.32E-07	3.06E-07	1.19E-06	1.43E-06	1.04E-06	3.90E-06
Chlorobenzene (CLC6H5)	4.37E-07	3.09E-07	1.20E-06	1.30E-06	9.45E-07	3.55E-06
Chloroform (CHCL3)	2.91E-06	2.06E-06	8.01E-06	9.36E-06	6.81E-06	2.56E-05
1,2-Dichloroethane (12DCLE)	1.88E-06	1.33E-06	5.18E-06	5.73E-06	4.17E-06	1.57E-05
1,2-Dichloroethene (12DCE)	5.89E-06	4.17E-06	1.62E-05	1.82E-05	1.33E-05	4.98E-05
1,3-Dinitrobenzene (13DNB)	2.09E-10	1.48E-10	5.77E-10	5.19E-10	3.78E-10	1.42E-09
Methylene Chloride (CH2CL2)	7.36E-07	5.21E-07	2.03E-06	2.11E-06	1.54E-06	5.77E-06
1,1,2,2-Tetrachloroethane (TCLEA)	6.04E-06	4.27E-06	1.66E-05	1.89E-05	1.37E-05	5.15E-05
Tetrachloroethene (TCLEE)	8.61E-07	6.09E-07	2.37E-06	2.77E-06	2.02E-06	7.57E-06
Toluene (MEC6H5)	1.47E-07	1.04E-07	4.06E-07	3.65E-07	2.65E-07	9.96E-07
1,1,2-Trichloroethane (112TCE)	2.84E-07	2.01E-07	7.83E-07	8.44E-07	6.14E-07	2.31E-06
Trichloroethene (TRCLE)	5.08E-06	3.60E-06	1.40E-05	1.58E-05	1.15E-05	4.32E-05
Vinyl Chloride (C2H3CL)	1.93E-06	1.37E-06	5.33E-06	6.19E-06	4.50E-06	1.69E-05

(a) Derived using Liss and Slater (1974) surface water volatilization model and EPA (1987a) Gaussian dispersion model. Both models are described in detail in Appendix A.

(b) USATHAMA chemical codes listed in parentheses.

(c) Best case based on initial surface water concentrations, which were estimated assuming minimum groundwater discharge and maximum surface water dilution volume.

(d) Worst case based on initial surface water concentrations, which were estimated assuming maximum groundwater discharge and minimum surface water dilution volume.

TABLE 5-18

EXPOSURE PARAMETERS FOR THE EVALUATION OF WORKER INHALATION EXPOSURES TO CHEMICALS THAT HAVE VOLATILIZED FROM WATSON CREEK

Parameter	Value (a)
Exposure Duration	8 hrs/day
Exposure Frequency (a)	
H-Field (b)	193 days/yr
M-Field (c)	241 days/yr
New O-Field (d)	30 days/yr
Years Exposure (e)	20
Inhalation Rate (f)	2 m3/hr
Body Weight (g)	70 kg
Lifetime (h)	70 years

(a) Assumes a typical worker works 5 days each week, takes 2 weeks vacation, and is off 9 Federal holidays each year.
(b) Workers assumed to be present at H-Field 80% of the work days each year (personal communication, G. Nemeth, AEHA, 1990).
(c) Workers assumed to be present at M-Field every work day each year (personal communication, G. Nemeth, AEHA, 1990).
(d) Workers assumed to be present at New O-Field 30 days per year (personal communication, G. Nemeth, AEHA, 1990).
(e) Based on the time a typical civilian worker spends working at APG.
(f) Mean ventilation rate for male and female adults engaged in moderate activity (EPA 1985a).
(g) EPA (1989a).
(h) Based on EPA (1989a) standard assumption for a lifetime.

$$CDI = (C_a * IR * ED * EF * YE)/(BW * DY * YL) \qquad \text{(Eq. 4)}$$

where:

CDI = chronic daily intake (mg/kg-day);

C_a = exposure point concentration in air (mg/m^3), presented previously in Table 5-17;

IR = inhalation rate in m^3/hr (2 m^3/hr);

ED = exposure duration in hrs/day (8 hrs/day);

EF = exposure frequency in days/yr (193 days/yr -- H-Field; 241 days/yr -- M-Field; 30 days/yr -- New O-Field);

YE = years of exposure (20 yrs);

BW = average body weight over period of exposure (70 kg);

DY = days in a year (365 days/year); and

YL = period over which risk is being estimated, i.e., a lifetime (70 years) for potential carcinogens and the period of exposure for noncarcinogens (20 years).

Based on the assumptions and procedures outlined above, the estimated inhalation CDIs for workers at H-Field, M-Field, and New O-Field were calculated and are presented in Tables 5-19 through 5-21.

5.3.1.3.2 Acute Dermal and Inhalation Exposures to Chemicals Released During Explosions, Fires, or Volatilization of Subsurface Spills

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

TABLE 5-19

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR CURRENT INHALATION EXPOSURES AT H-FIELD (a)

Chemical (b)	RME Concentration (mg/m3) Low Estimate	RME Concentration (mg/m3) High Estimate	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c) Low Estimate	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c) High Estimate
Chemicals Exhibiting Carcinogenic Effects				
Benzene (C6H6)	1.9E-06	6.2E-06	6.6E-08	2.1E-07
Carbon Tetrachloride (CCL4)	4.3E-07	1.4E-06	1.5E-08	4.9E-08
Chloroform (CHCL3)	2.9E-06	9.4E-06	1.0E-07	3.2E-07
1,2-Dichloroethane (12DCLE)	1.9E-06	5.7E-06	6.5E-08	2.0E-07
Methylene Chloride (CH2CL2)	7.4E-07	2.1E-06	2.5E-08	7.3E-08
1,1,2,2-Tetrachloroethane (TCLEA)	6.0E-06	1.9E-05	2.1E-07	6.5E-07
Tetrachloroethene (TCLEE)	8.6E-07	2.8E-06	3.0E-08	9.6E-08
1,1,2-Trichloroethane (112TCE)	2.8E-07	8.4E-07	9.8E-09	2.9E-08
Trichloroethene (TRCLE)	5.1E-06	1.6E-05	1.8E-07	5.5E-07
Vinyl Chloride (C2H3CL)	1.9E-06	6.2E-06	6.7E-08	2.1E-07
Chemicals Exhibiting Noncarcinogenic Effects				
Chlorobenzene (CLC6H5)	4.4E-07	1.3E-06	5.3E-08	1.6E-07
Methylene Chloride (CH2CL2)	7.4E-07	2.1E-06	8.9E-08	2.6E-07
Toluene (MEC6H5)	1.5E-07	3.6E-07	1.8E-08	4.4E-08

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

TABLE 5-20

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR CURRENT INHALATION EXPOSURES AT M-FIELD (a)

Chemical (b)	RME Concentration (mg/m3) Low Estimate	RME Concentration (mg/m3) High Estimate	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c) Low Estimate	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c) High Estimate
Chemicals Exhibiting Carcinogenic Effects				
Benzene (C6H6)	1.4E-06	4.5E-06	5.9E-08	1.9E-07
Carbon Tetrachloride (CCL4)	3.1E-07	1.0E-06	1.3E-08	4.5E-08
Chloroform (CHCL3)	2.1E-06	6.8E-06	8.9E-08	2.9E-07
1,2-Dichloroethane (12DCLE)	1.3E-06	4.2E-06	5.7E-08	1.8E-07
Methylene Chloride (CH2CL2)	5.2E-07	1.5E-06	2.2E-08	6.6E-08
1,1,2,2-Tetrachloroethane (TCLEA)	4.3E-06	1.4E-05	1.8E-07	5.9E-07
Tetrachloroethene (TCLEE)	6.1E-07	2.0E-06	2.6E-08	8.7E-08
1,1,2-Trichloroethane (112TCE)	2.0E-07	6.1E-07	8.7E-09	2.6E-08
Trichloroethene (TRCLE)	3.6E-06	1.2E-05	1.6E-07	5.0E-07
Vinyl Chloride (C2H3CL)	1.4E-06	4.5E-06	5.9E-08	1.9E-07
Chemicals Exhibiting Noncarcinogenic Effects				
Chlorobenzene (CLC6H5)	3.1E-07	9.4E-07	4.7E-08	1.4E-07
Methylene Chloride (CH2CL2)	5.2E-07	1.5E-06	7.9E-08	2.3E-07
Toluene (MEC6H5)	1.0E-07	2.7E-07	1.6E-08	4.0E-08

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

TABLE 5-21

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR CURRENT INHALATION EXPOSURES AT NEW O-FIELD (a)

Chemical (b)	RME Concentration (mg/m3)		Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)	
	Low Estimate	High Estimate	Low Estimate	High Estimate
Chemicals Exhibiting Carcinogenic Effects				
Benzene (C6H6)	5.3E-06	1.7E-05	2.8E-08	9.0E-08
Carbon Tetrachloride (CCL4)	1.2E-06	3.9E-06	6.4E-09	2.1E-08
Chloroform (CHCL3)	8.0E-06	2.6E-05	4.3E-08	1.4E-07
1,2-Dichloroethane (12DCLE)	5.2E-06	1.6E-05	2.8E-08	8.4E-08
Methylene Chloride (CH2CL2)	2.0E-06	5.8E-06	1.1E-08	3.1E-08
1,1,2,2-Tetrachloroethane (TCLEA)	1.7E-05	5.1E-05	8.9E-08	2.8E-07
Tetrachloroethene (TCLEE)	2.4E-06	7.6E-06	1.3E-08	4.1E-08
1,1,2-Trichloroethane (112TCE)	7.8E-07	2.3E-06	4.2E-09	1.2E-08
Trichloroethene (TRCLE)	1.4E-05	4.3E-05	7.5E-08	2.3E-07
Vinyl Chloride (C2H3CL)	5.3E-06	1.7E-05	2.9E-08	9.1E-08
Chemicals Exhibiting Noncarcinogenic Effects				
Chlorobenzene (CLC6H5)	1.2E-06	3.5E-06	2.3E-08	6.7E-08
Methylene Chloride (CH2CL2)	2.0E-06	5.8E-06	3.8E-08	1.1E-07
Toluene (MEC6H5)	4.1E-07	1.0E-06	7.6E-09	1.9E-08

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

5.3.2 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria are described in Chapter 4 to provide the analytical framework for the characterization of human health impacts. The health effects criteria that were used to derive estimates of risk for workers exposed via inhalation to chemicals that have volatilized from Watson Creek surface water are presented in this section in Table 5-22. No inhalation toxicity criteria are available for 1,2-dichloroethene and 1,3-dinitrobenzene. Therefore, potential risks associated with exposure to these chemicals were not evaluated quantitatively. However, the contribution of these chemicals to the overall estimates of risk for the worker inhalation pathway is discussed qualitatively in the risk characterization section. Toxicity summaries for all chemicals of potential concern for the inhalation pathway as well as the toxicological basis of the health effects criteria presented Table 5-22 are provided in Appendix B.

TABLE 5-22

INHALATION CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN VOLATILIZING FROM WATSON CREEK SURFACE WATER

Chemical	Chronic Reference Dose (mg/kg-day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg-day)-1	EPA Weight of Evidence Classification (c)	Slope Factor Source
Benzene	--	--	--	IRIS	2.90E-02	A	IRIS
Carbon Tetrachloride	--	--	--	IRIS	1.30E-01	B2	IRIS
Chlorobenzene	5.00E-03	10,000	Liver/Kidney	HEAST	--	D	HA
Chloroform	--	--	--	IRIS	8.10E-02	B2	IRIS
1,2-Dichloroethane	--	--	--	IRIS	9.10E-02	B2	IRIS
cis-1,2-Dichloroethene	--	--	--	HEAST	--	--	--
trans-1,2-Dichloroethene	--	--	--	IRIS	--	--	--
1,3-Dinitrobenzene	--	--	--	IRIS	--	--	IRIS
Methylene Chloride	3.00E+00	100	Liver	HEAST	1.40E-02	B2	IRIS
1,1,2,2-Tetrachloroethane	--	--	--	--	2.00E-01	C	IRIS
Tetrachloroethene	--	--	--	IRIS	3.30E-03	B2	HEAST
Toluene	5.71E-01 (d)	100	CNS	HEAST	--	D	IRIS
1,1,2-Trichloroethane	--	--	--	IRIS	5.70E-02	C	IRIS
Trichloroethene	--	--	--	IRIS	1.70E-02	B2	HEAST
Vinyl Chloride	--	--	--	--	2.95E-01	A	HEAST

(a) Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors including the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = No evidence of carcinogenicity.

(d) Reported RfD of 2.00 mg/m3 was converted to mg/kg-day by assuming a 70 kg adult inhales 20 m3 of air per day.

OTE: IRIS = Integrated Risk Information System - December 1, 1990.
HEAST = Health Effects Assessment Summary Tables - July 1, 1990.
HA = Health Advisory - March 1, 1987.
-- = No information available.

Complete toxicity summaries of the lethal chemical agents, which include discussions of available acute criteria, are provided in Appendix B.

5.3.3 RISK CHARACTERIZATION

In this section, the human health risks associated with O-Field are presented. Potential risks under current land-use conditions are presented in Section 5.3.3.1, and those under hypothetical future land-use conditions are presented in Section 5.3.3.2. Risks under current land-use conditions were evaluated quantitatively, while those under hypothetical future land-use conditions were evaluated qualitatively.

5.3.3.1 Potential Risks Under Current Land-Use Conditions

The exposure pathway selected for quantitative evaluation under current land-use conditions is:

- Chronic exposures in workers via inhalation of chemicals that have volatilized from Watson Creek surface water.

The potential risks associated with the pathway are discussed below.

5.3.3.1.1 Risk to Workers from Inhalation of Chemicals Volatilizing from Watson Creek

Tables 5-23 through 5-25 present estimated CDIs and risks for workers at H-Field, M-Field, and New O-Field exposed via inhalation to chemicals that have volatilized from Watson Creek. Two exposure and risk estimates are provided for receptors at each location to reflect the range of modeled air concentrations. As discussed previously, high-estimate and low-estimate air concentrations were calculated based on variations in the size of the groundwater plume discharge area in Watson Creek shown by Vroblesky et al. (1990). High-estimate CDIs and risks reflect exposure to air concentrations resulting from a maximum groundwater discharge volume and a minimum surface water dilution volume. Low-estimate CDIs and risks reflect exposure to air concentrations resulting from a minimum groundwater discharge volume and a maximum surface water dilution volume.

For H-Field receptors, the upper-bound excess lifetime cancer risk ranges from $8x10^{-8}$ to $3x10^{-7}$. For M-Field receptors, the upper-bound excess lifetime cancer risk ranges from $7x10^{-8}$ to $2x10^{-7}$. For New O-Field receptors, the upper-bound excess lifetime cancer risk ranges from $4x10^{-8}$ to $1x10^{-7}$. The risk estimates are below the $1x10^{-6}$ risk level often used by regulatory agencies to determine the need for corrective action at a site. For all receptors, the Hazard Index is less than 1, indicating that inhalation exposures evaluated are unlikely to be associated with noncarcinogenic health effects.

Because toxicity criteria are not available, these risk estimates do not include risks associated with exposure to 1,3-dinitrobenzene and 1,2-dichlorethene. Exposure to 1,3-dinitrobenzene is unlikely to contribute significantly to risk estimates because the estimated exposure concentrations of this

TABLE 5-23

POTENTIAL RISKS ASSOCIATED WITH CURRENT INHALATION EXPOSURES AT H-FIELD (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk Low Estimate	High Estimate
Benzene (C6H6)	6.6E-08	2.1E-07	2.9E-02	A	2E-09	6E-09
Carbon Tetrachloride (CCL4)	1.5E-08	4.9E-08	1.3E-01	B2	2E-09	6E-09
Chloroform (CHCL3)	1.0E-07	3.2E-07	8.1E-02	B2	8E-09	3E-08
1,2-Dichloroethane (12DCLE)	6.5E-08	2.0E-07	9.1E-02	B2	6E-09	2E-08
Methylene Chloride (CH2CL2)	2.5E-08	7.3E-08	1.4E-02	B2	4E-10	1E-09
1,1,2,2-Tetrachloroethane (TCLEA)	2.1E-07	6.5E-07	2.0E-01	C	4E-08	1E-07
Tetrachloroethene (TCLEE)	3.0E-08	9.6E-08	3.3E-03	B2	1E-10	3E-10
1,1,2-Trichloroethane (112TCE)	9.8E-09	2.9E-08	5.7E-02	C	6E-10	2E-09
Trichloroethene (TRCLE)	1.8E-07	5.5E-07	1.7E-02	B2	3E-09	9E-09
Vinyl Chloride (C2H3CL)	6.7E-08	2.1E-07	2.9E-01	A	2E-08	6E-08
TOTAL	--	--	--	--	8E-08	3E-07

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio Low Estimate	High Estimate
robenzene (CLC6H5)	5.3E-08	1.6E-07	5.0E-03	10,000	Liver, kidney	1E-05	3E-05
ylene Chloride (CH2CL2)	8.9E-08	2.6E-07	3.0E+00	100	Liver	3E-08	9E-08
Toluene (MEC6H5)	1.8E-08	4.4E-08	5.7E-01	100	CNS	3E-08	8E-08
HAZARD INDEX	--	--	--	--	--	< 1 (1E-05)	< 1 (3E-05)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) USEPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

TABLE 5-24

POTENTIAL RISKS ASSOCIATED WITH CURRENT INHALATION EXPOSURES AT M-FIELD (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk Low Estimate	High Estimate
Benzene (C6H6)	5.9E-08	1.9E-07	2.9E-02	A	2E-09	6E-09
Carbon Tetrachloride (CCL4)	1.3E-08	4.5E-08	1.3E-01	B2	2E-09	6E-09
Chloroform (CHCL3)	8.9E-08	2.9E-07	8.1E-02	B2	7E-09	2E-08
1,2-Dichloroethane (12DCLE)	5.7E-08	1.8E-07	9.1E-02	B2	5E-09	2E-08
Methylene Chloride (CH2CL2)	2.2E-08	6.6E-08	1.4E-02	B2	3E-10	9E-10
1,1,2,2-Tetrachloroethane (TCLEA)	1.8E-07	5.9E-07	2.0E-01	C	4E-08	1E-07
Tetrachloroethene (TCLEE)	2.6E-08	8.7E-08	3.3E-03	B2	9E-11	3E-10
1,1,2-Trichloroethane (112TCE)	8.7E-09	2.6E-08	5.7E-02	C	5E-10	2E-09
Trichloroethene (TRCLE)	1.6E-07	5.0E-07	1.7E-02	B2	3E-09	8E-09
Vinyl Chloride (C2H3CL)	5.9E-08	1.9E-07	2.9E-01	A	2E-08	6E-08
TOTAL	--	--	--	--	7E-08	2E-07

Chemicals Exhibiting rcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio Low Estimate	High Estimate
lorobenzene (CLC6H5)	4.7E-08	1.4E-07	5.0E-03	10,000	Liver, kidney	9E-06	3E-05
Methylene Chloride (CH2CL2)	7.9E-08	2.3E-07	3.0E+00	100	Liver	3E-08	8E-08
Toluene (MEC6H5)	1.6E-08	4.0E-08	5.7E-01	100	CNS	3E-08	7E-08
HAZARD INDEX	--	--	--	--	--	< 1 (9E-06)	< 1 (3E-05)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) USEPA Weight of Evidence for Carcinogenic Effects:
  [A] = Human carcinogen based on adequate evidence from human studies;
  [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and
  [C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

TABLE 5-25

POTENTIAL RISKS ASSOCIATED WITH CURRENT INHALATION EXPOSURES AT NEW O-FIELD (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk Low Estimate	High Estimate
Benzene (C6H6)	2.8E-08	9.0E-08	2.9E-02	A	8E-10	3E-09
Carbon Tetrachloride (CCL4)	6.4E-09	2.1E-08	1.3E-01	B2	8E-10	3E-09
Chloroform (CHCL3)	4.3E-08	1.4E-07	8.1E-02	B2	3E-09	1E-08
1,2-Dichloroethane (12DCLE)	2.8E-08	8.4E-08	9.1E-02	B2	3E-09	8E-09
Methylene Chloride (CH2CL2)	1.1E-08	3.1E-08	1.4E-02	B2	2E-10	4E-10
1,1,2,2-Tetrachloroethane (TCLEA)	8.9E-08	2.8E-07	2.0E-01	C	2E-08	6E-08
Tetrachloroethene (TCLEE)	1.3E-08	4.1E-08	3.3E-03	B2	4E-11	1E-10
1,1,2-Trichloroethane (112TCE)	4.2E-09	1.2E-08	5.7E-02	C	2E-10	7E-10
Trichloroethene (TRCLE)	7.5E-08	2.3E-07	1.7E-02	B2	1E-09	4E-09
Vinyl Chloride (C2H3CL)	2.9E-08	9.1E-08	2.9E-01	A	8E-09	3E-08
TOTAL	--	--	--	--	4E-08	1E-07

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) Low Estimate	High Estimate	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio Low Estimate	High Estimate
orobenzene (CLC6H5)	2.3E-08	6.7E-08	5.0E-03	10,000	Liver, kidney	5E-06	1E-05
.thylene Chloride (CH2CL2)	3.8E-08	1.1E-07	3.0E+00	100	Liver	1E-08	4E-08
Toluene (MEC6H5)	7.6E-09	1.9E-08	5.7E-01	100	CNS	1E-08	3E-08
HAZARD INDEX	--	--	--	--	--	< 1 (5E-06)	< 1 (1E-05)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 1,2-dichloroethene and 1,3-dinitrobenzene.

(b) USATHAMA chemical codes listed in parentheses.

(c) USEPA Weight of Evidence for Carcinogenic Effects:
- [A] = Human carcinogen based on adequate evidence from human studies;
- [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and
- [C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

chemical were low relative to the other chemicals of concern and because the inhalation toxicity of 1,3-dinitrobenzene is likely equal to or less than the other chemicals of concern. Although 1,2-dichloroethene is not very toxic relative to many of the other chemicals of concern, it may be present in air at concentrations an order-of-magnitude or more greater than the other chemicals of concern and therefore could add to the estimates of risk given above. However, resulting risks are unlikely to exceed the 1×10^{-6} risk level or a Hazard Index greater than one for any of the receptors evaluated.

5.3.3.1.2 Risks Associated with Acute Exposures to Chemical Agents Released as a Result of an Explosion or Spill

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-2

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-3

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-4

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-5

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-6

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Figure 5-7

THIS FIGURE HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

5.3.3.2 Potential Risks Under Hypothetical Future Land-Use Conditions

The three exposure pathways selected for qualitative evaluation under hypothetical future land-use conditions are:

- Dermal contact and/or incidental ingestion of chemicals in surface soils by workers at O-Field;
- Inhalation of chemicals that have volatilized from surface water by workers at O-Field; and
- Dermal contact and incidental ingestion by persons swimming in the Gunpowder River.

If land-use changed in the future, these pathways could result in additional exposures and risks above those predicted under current use conditions. The magnitude of exposures and risks would vary based on the types and quantities of chemicals present, as well as on the frequency and duration of expected exposure.

It is not possible to predict the magnitude of potential direct contact exposures to chemicals in surface soils at O-Field because no surface soil sampling has been conducted. However, given the past disposal and demilitarization activities at O-Field, significant soil contamination is likely. A variety of chemicals could be present in surface soils, including:

- Some moderately persistent lethal agents (e.g., mustard can form an oxide coating and remain in pure form in soils; VX is moderately persistent);
- Persistent incapacitating agents (e.g., adamsite has a low mobility and high persistence in soils);
- Toxic breakdown products (e.g., chlorovinyl arsenous oxide retains lewisite's vesicant properties);
- PAHs and petroleum-related compounds (probably present as a result of past demilitarization activities which involved extensive surface burning);
- Phthalates (components of plasticized white phosphorus); and
- A variety of miscellaneous laboratory and production waste compounds (e.g., methylquinoline, methyl isopropyl ketone).

The concentrations of some of these chemicals are likely to be high in O-Field soils, particularly in some localized areas where spills or disposal occurred. As a result, the potential exists for significant exposures to chemicals in surface soils if use restrictions were lifted in the future. The chemicals potentially present in surface soils have been associated with a variety of toxic effects, ranging from acute lethality (e.g., mustard, VX) to cancer (e.g., PAHs, phthalates). Because of the potentially high concentrations present in surface soil and the severe nature of possible toxic effects, it is concluded that direct contact exposures with chemicals in soils at O-Field would result in significant health risks in exposed individuals.

Potential risks to workers exposed to chemicals that have volatilized from surface water are likely to be less than those associated with direct contact exposures. The risks for this pathway would probably be within an order-of-magnitude of those estimated for workers at New O-Field given that workers at Old O-Field would be closer to the emission source and could be exposed more frequently than current workers at New O-Field. Thus, excess lifetime cancer risks in the range of 10^{-7} to 10^{-6} would be possible. Hazard Indices would remain below one.

The greatest source of risks to persons swimming in the Gunpowder River near O-Field is exposure to arsenic in surface water via incidental ingestion. Arsenic, a known human carcinogen with a relatively high cancer slope factor 2.0 $(mg/kg\text{-}day)^{-1}$, is the most toxic of the chemicals detected in Gunpowder River surface water. However, exposure to arsenic in surface water while swimming is unlikely to pose a significant risk. For example, a person who swam in the Gunpowder River near O-Field every day of his 70-year life and incidentally ingested 100 ml of water each day while swimming would experience only a 4×10^{-6} excess lifetime cancer risk if exposed to the maximum detected concentration of 90 $\mu g/L$.

None of the other chemicals detected in Gunpowder River surface water would add significantly to this risk, given their lower toxicity relative to that of arsenic. Further, dermal absorption of arsenic or any of the other metals present in surface water would contribute negligibly to overall risks because metals are not appreciably absorbed through the skin.

5.4 ECOLOGICAL ASSESSMENT

This section assesses potential ecological impacts associated with the chemicals of potential concern at the O-Field study area in the absence of remediation. The methods used to assess ecological impacts follow those outlined in Chapter 4 and roughly parallel those used in the human health risk assessment. Below, potentially exposed populations (receptors) are identified. Then information on exposure and toxicity is combined to derive estimates of potential impact in these populations. It is emphasized that this ecological assessment is a predictive assessment. Comprehensive field studies of ecological impacts have not been conducted at O-Field.

This ecological assessment is divided into four principal sections. Section 5.4.1 describes the habitats in the area and potential receptor species or species groups selected for evaluation. Section 5.4.2 evaluates and provides estimates of potential exposures for the chemicals and receptors of potential concern. Section 5.4.3 summarizes relevant toxicity information for the chemicals of potential concern, and Section 5.4.4 provides estimates of ecological impact.

5.4.1 RECEPTOR CHARACTERIZATION

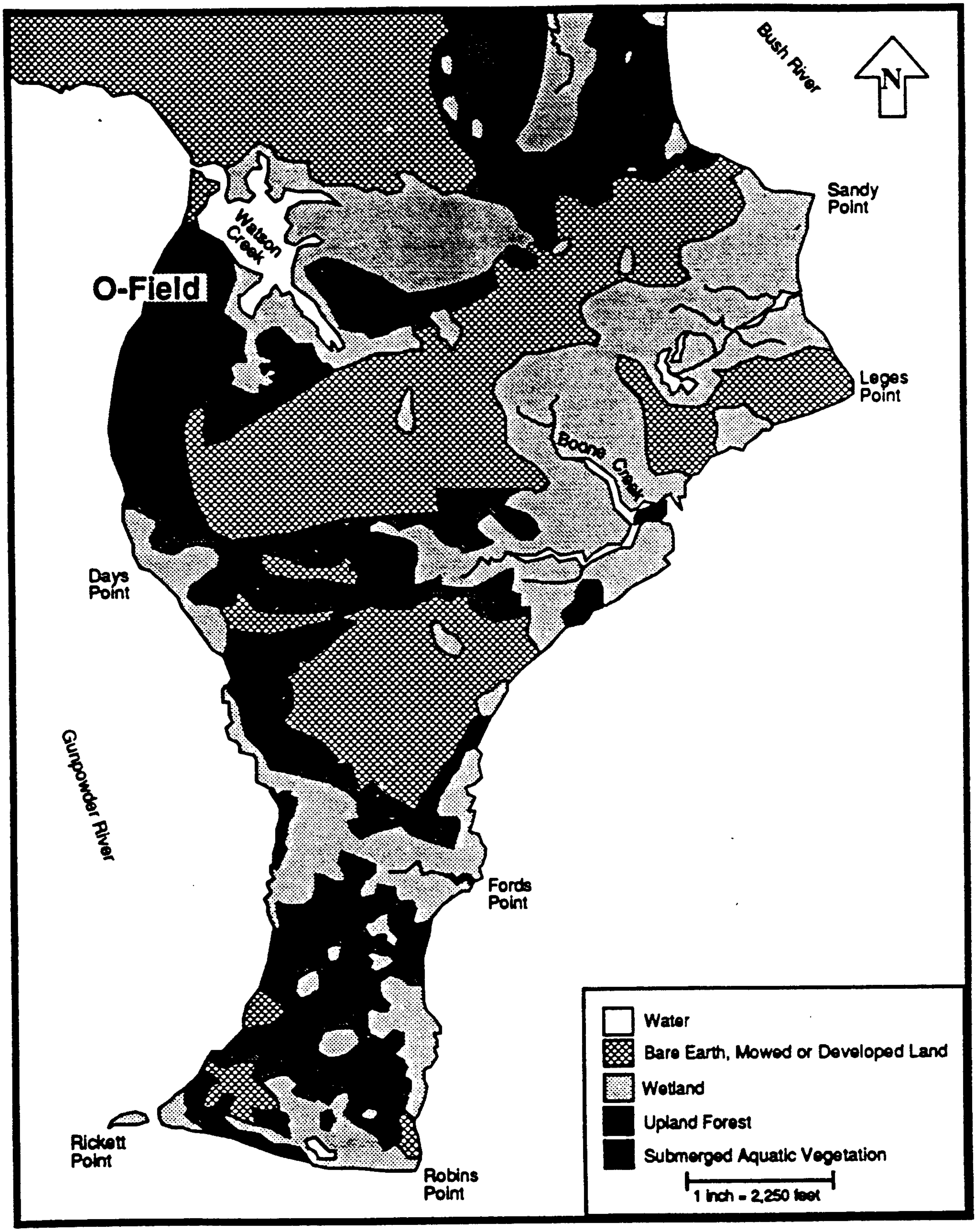
The O-Field study area is a mixture of forests, marsh, and fields. Old O-Field consists principally of upland forest, with a tidal, emergent marsh surrounding Watson Creek. New O-Field consists principally of fields with adjacent marsh and forest. Surface water in the study area consists of Watson Creek, the Gunpowder River, and a small intermittent stream located between New and Old O-Fields. The intermittent stream flows only during periods of high water, typically during the rainy winter months. Figure 5-8 presents some of the principal habitat characteristics at O-Field and the surrounding area.

The study area probably supports a variety of wildlife species, given the presence of forest, field, and wetland habitats. Typical forest species of the area probably include gray fox (*Urocyon cinereoargenteus*), gray squirrel (*Sciurus carolinensis*), deer (*Odocoileus virginianus*), and woodpeckers (*Dendrocopos* spp.). Field species probably include field mice (*Peromyscus leucopus*, *Mus musculus*), voles (*Microtus* spp.), rabbit (*Sylvilagus floridanus*), mourning dove (*Zenaidura macroura*), killdeer (*Charadrius vociferus*), hawks (*Buteo jamaicensis*, *Circus cyaneus*), and a variety of song birds. Wetland species likely include muskrat (*Ondatra zibethicus*), great blue heron (*Ardea herodias*) and other wading bird species, mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*) and other dabbling ducks, and a variety of shorebirds, including spotted sandpiper (*Actitis macularia*), yellowlegs (*Tringa* spp.), and rails (*Rallus* spp.). Bald eagle (*Haliaeetus leucocephalus*) are known to forage in the area.

Watson Creek probably provides aquatic habitat for a variety of freshwater and estuarine aquatic life. Freshwater and estuarine fish that have been caught in Watson Creek include largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), black drum (*Pogonias cromis*), carp (*Cyprinus carpio*), white perch (*Morone americana*), striped bass (*Morone saxatilis*), yellow perch (*Perca flavenscens*), bluefish (*Pomatomus saltatrix*), croaker (*Micropogonias undulatus*), and Atlantic silverside (*Menidia menidia*) (AEHA 1978, 1985). Other fish species that may be present year round or seasonally in Watson Creek or in the adjacent Gunpowder River include various species of herrings

Figure 5-8

Habitat Characteristics of the O-Field Study Area At Aberdeen Proving Ground



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(*Alosa* spp., *Anchoa mitchilli*, *Brevoortia tyrannus*) and catfish (*Ictalurus* spp.). Invertebrates identified in Watson Creek sediments include polychaetes, isopods, amphipods, and chironomids (AEHA 1985).

As discussed in Chapter 4, it is not feasible to assess potential impacts in each of the species that may be present at O-Field, and for this reason indicator species or species groups were selected for further evaluation. The selection of indicator species for the O-Field study area was driven by several factors including the potential for exposure, sensitivity or susceptibility to chemical exposures, the availability of chemical data for potential exposure media, ecological significance, and societal value. The indicator species or species groups selected for evaluation at O-Field based on these considerations are a subset of those identified as potential indicators in Chapter 4 and are listed below along with the rationale for their selection.

Aquatic Species

Fish:

- Herrings. Juveniles of several members in this family (i.e., blueback herring, bay anchovy, menhaden) may use Watson Creek as a nursery area and thus are vulnerable to population impacts due to juvenile mortality. Further, several species within this family are commercially important.

Invertebrates:

- Benthic invertebrates. They are susceptible to exposures to chemicals that are present in sediments and sediment pore water following release from groundwater to surface water. They also are an important component of the diet of many birds, as well as adult and juvenile fish.

Terrestrial Species

Birds:

- Great blue heron. They are likely to be present at O-Field frequently and are susceptible to exposure to chemicals in Watson Creek. Several of the chemicals of potential concern in Watson Creek surface water can bioaccumulate in fish, the principal food item in the diet of great blue herons.

- Spotted sandpiper. This species was selected for evaluation because of its probable frequent use of O-Field and its susceptibility to exposure to chemicals in Watson Creek. This species feeds principally on insects (terrestrial and aquatic larvae and adults). Several of the chemicals of potential concern in Watson Creek can bioaccumulate in aquatic insects, often to a much greater degree than in fish.

Mammals:

- Muskrat. This species is selected for evaluation because its small home range and dependence on aquatic vegetation for food make it susceptible to exposures to chemicals in Watson Creek. Muskrat also is a commercially important furbearer at APG.

The other species listed in Chapter 4 as potential indicator species were not selected for evaluation at O-Field either because (1) O-Field does not provide optimal or preferred habitat; or (2) they occur in the area but their exposures are likely to be less than or equal to those for a selected species from the same taxonomic class (e.g., birds, mammals). For example, green frogs are unlikely to be present in Watson Creek, given the creek's brackish nature. White perch, striped bass, and catfish would be present only occasionally in Watson Creek, as these species prefer the more open waters of the Gunpowder River and the Chesapeake Bay. Raccoon are likely to be more common along streams in wooded areas, than in the estuarine marsh environment of Watson Creek. Killifish and bluegill are probable residents of Watson Creek, but their exposures are not likely to be greater than those of herring. Finally, mallard (an aquatic herbivore) and bald eagle (which forages over tens of square miles) would experience significantly lower exposure than the other bird species selected for evaluation.

Appendix D provides species profiles for the vertebrate species selected for evaluation. These profiles should be consulted for information on the ecology of the selected indicator species. Such profiles are not provided for benthic invertebrates due to the large diversity of species comprising this broadly defined receptor group.

5.4.2 POTENTIAL EXPOSURE PATHWAYS AND QUANTIFICATION OF EXPOSURE

In this section, the potential pathways by which the selected indicator species and species groups could be exposed to the chemicals of potential concern at O-Field are discussed, and exposure is quantified for selected exposure pathways. This exposure assessment focuses on potential exposures to chemicals in surface water and sediment. No pathways exist by which wildlife could be exposed to chemicals of potential concern in groundwater[6] or subsurface soils, which are the only other media for which sampling data are available.

Potential exposures are evaluated separately in the following sections for aquatic and terrestrial receptors. For both aquatic and terrestrial wildlife exposures, it is assumed that all mercury in Watson Creek and the Gunpowder River is in the inorganic form. It is recognized that inorganic mercury present in sediments can be methylated by microorganisms to methylmercury. However, a review of the literature on mercury levels in sediments shows that organic mercury normally makes up 0.01-1% of the total mercury concentration in freshwater and marine sediments (Battelle 1987, Stary et al. 1980) and that total mercury concentration is virtually an estimate of inorganic mercury concentrations (Jackson 1986).

5.4.2.1 Aquatic Life Exposures

As discussed in Chapter 4, aquatic life could be exposed to chemicals in surface water and sediment by several pathways. However, most available aquatic toxicity data express toxicity as a function of the concentration in the exposure medium (i.e., surface water or sediment concentration). To be consistent with available toxicity data, exposures to aquatic life were evaluated in this assessment by using surface water and sediment concentrations for Watson Creek and the Gunpowder River.

Both measured and estimated values were used to assess potential aquatic life exposures. Measured concentrations were used to evaluate surface water and sediment exposures to nonvolatile chemicals of potential concern (i.e., inorganic chemicals, phthalates, PAHs). For these chemicals, the exposure concentrations are the lower values of the 95% confidence limits on the arithmetic means and the maximum detected concentrations for samples within Watson Creek and in the Gunpowder River near

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[6] Groundwater released to surface water is evaluated as surface water exposure.

Watson Creek. The surface water and sediment exposure point concentrations for nonvolatile chemicals are presented in Tables 5-26 and 5-27, respectively.

Exposure concentrations of volatile organic chemicals released to Watson Creek from groundwater were estimated, however. As discussed previously, because of the dynamic nature of groundwater/surface water interactions at O-Field, it is not appropriate to use measured surface water concentrations obtained from one or a few sampling episodes to model volatile releases (see Section 5.3.1.3.1). For this assessment, therefore, the estimated surface water concentrations presented previously in Table 5-16 were used to evaluate exposures to aquatic species. These concentrations are estimates of the average water-column chemical concentrations within the groundwater discharge area in Watson Creek between groundwater discharge events. They do not represent exposure concentrations across all of Watson Creek, which are likely to be negligible compared to concentrations near the discharge area. They nevertheless were used as a conservative estimate of exposure concentrations for Watson Creek. The "high estimates" presented in Table 5-16 were used in this assessment to assess maximum possible exposures.

The estimated concentrations also do not represent the concentrations to which benthic species would be exposed in the discharge area. Exposure concentrations for benthic species were higher than those for water-column species, because these species are exposed to undiluted groundwater as it discharges directly through the sediments. Vroblesky et al. (1990) showed that concentrations in the sediment pore water were equivalent to those measured in groundwater in wells near the discharge area. Therefore, for this assessment, chemical concentrations in groundwater wells nearest the Watson Creek shoreline were used to evaluate exposures in benthic species in the discharge zone. The exposure concentration is the lower value of the 95% upper confidence limit on the arithmetic mean and the maximum detected concentration for wells nearest Watson Creek. The exposure area concentrations for the evaluation of impacts on benthic species are presented in Table 5-28.

In addition to the volatile organic chemicals, surface water (water-column and sediment pore water) concentrations were estimated for thiodiglycol, 1,4-dithiane, methylphosphonic acid, and 1,3-dinitrobenzene. These chemicals were detected in wells near the Watson Creek shoreline but were not analyzed for in Watson Creek surface water.

5.4.2.2 Terrestrial Wildlife Exposures

As discussed in Chapter 4, terrestrial wildlife could be exposed to chemicals in surface water and sediment by a variety of pathways. Adequate data are not available to assess wildlife exposures via all pathways, however, so only exposures via ingestion of surface water and food were selected for consideration in the ecological assessments for the various APG study areas. For this assessment of O-Field, only ingestion of contaminated food was evaluated. Ingestion of surface water was not selected for evaluation because exposures and impacts via this pathway are likely to be insignificant compared to those from the ingestion of food that has accumulated chemicals at concentrations greater than those in the surrounding media. Terrestrial exposures were evaluated for chemicals of potential concern in Watson Creek only; the numbers and concentrations of chemicals detected in the Gunpowder River were less than those reported for Watson Creek.

Chemical concentrations in wildlife food at O-Field were estimated in this assessment using BCFs and chemical concentrations in Watson Creek. BCFs provide a measure of the extent of chemical partitioning at equilibrium between a biological medium such as fish or plants and an external medium such as water. For most chemicals and most situations, water is considered to be the predominant

TABLE 5-26

EXPOSURE CONCENTRATIONS OF NON-VOLATILE CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AT O-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
WATSON CREEK (d)				
Organic Chemicals:				
Di-n-octylphthalate (DNOP)	5.2	5.4	8.0	5.4
Inorganic Chemicals:				
Antimony (SB)	92	220	149	149
Arsenic [Total] (AS)	71	110	126	110
Arsenic [III] (ASIII)	61	71	95	71
Arsenic [V] (ASV)	22	63	66	63
Boron (B)	500	530	785	530
Cadmium (CD)	2.1	2.5	18.0	2.5
Copper (CU)	1.5	1.7	3.3	1.7
Fluoride (F)	150	710	350	350
Iron (FE)	230	440	794	440
Manganese (MN)	690	750	874	750
Mercury (HG)	0.2	0.3	0.4	0.3
Selenium (SE)	58	69	94	69
Sulfate (SO4)	520,000	690,000	960,000	690,000
Zinc (ZN)	21	21	168	41
GUNPOWDER RIVER (e)				
Organic Chemicals:				
bis(2-Ethylhexyl)phthalate (B2EHP)	11	23,000	24	24
Inorganic Chemicals:				
Antimony (SB)	120	130	126	126
Arsenic [Total] (AS)	58	3,300,000	90	90
Arsenic [III] (ASIII)	68	80	75	75
Arsenic [V] (ASV)	10	NC	15	15
Boron (B)	970	1,100	1,020	1,020
Manganese (MN)	1,450	730	562	562
Selenium (SE)	47	58	53	53
Sulfate (SO4)	440,000	NC	473,000	473,000

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Samples: 1 through 20.
(e) Samples: 21, 22, and 23.

NC = Not calculated. Chemical analyzed in only 2 samples.

TABLE 5-27

EXPOSURE CONCENTRATIONS OF NON-VOLATILE CHEMICALS OF POTENTIAL CONCERN IN SEDIMENT AT O-FIELD

(Concentrations reported in mg/kg)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
WATSON CREEK (d)				
Organic Chemicals:				
PAHs [carcinogenic]	0.76	0.85	4.67	0.85
PAHs [noncarcinogenic]	0.64	0.77	4.14	0.77
Phthalates				
Di-n-butylphthalate (DNBP)	0.22	0.30	1.55	0.30
Diethylphthalate (DEP)	0.29	0.37	2.36	0.37
Dimethylphthalate (DMP)	0.15	0.77	0.86	0.77
bis(2-Ethylhexyl)phthalate (B2EHP)	0.38	0.56	2.46	0.56
Inorganic Chemicals:				
Ammonia (NH3)	110	260	252	252
Antimony (SB)	3.0	3.7	6.0	3.7
Beryllium (BE)	0.8	0.9	1.6	0.9
Boron (B)	6.5	8.7	19.7	8.7
Copper (CU)	25	33	66.7	33
Mercury (HG)	0.4	0.5	2.6	0.5
Nitrite (NO2)	2.0	2.3	14.5	2.3
Thallium (TL)	1.8	2.3	5.3	2.3
Zinc (ZN)	130	160	394	160
GUNPOWDER RIVER (e)				
Inorganic Chemicals:				
Ammonia (NH3)	25	3,000,000	56	56
Boron (B)	1.0	50,000,000	3.2	3.2
Nitrite (NO2)	1.3	1.4	1.4	1.4

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Samples: 1 through 10, 13 through 20, 1S through 11S, and 20S.
(e) Samples: 24S through 27S.

source of chemical residues in aquatic organisms (Neff 1979).[7] Use of the BCFs to estimate chemical concentrations in aquatic life in Watson Creek is therefore a reasonable approach in the absence of measured tissue concentrations.

Information on the bioconcentration potential of the chemicals of potential concern in water from Watson Creek was obtained from the available literature. A summary of bioconcentration data for the chemicals of potential concern is presented in the chemical-specific ecological toxicity profiles presented in Appendix C. In selecting BCFs for use in this risk assessment, the following screening procedures were used.

- Data from laboratory studies were generally used in preference to field data because laboratory studies involve considerably greater control of the parameters affecting bioaccumulation (e.g., chemical concentration, exposure duration). Field data were used only if no laboratory data were available or if studies show that accumulation from food contributes more significantly than accumulation from water. In these latter cases, a bioaccumulation factor (BAF), which is the ratio of the concentration in the fish to that in water with food-chain effects included, is presented.

- Whole-body BCFs were used in preference to muscle or organ-specific BCFs because wildlife typically ingest an entire organism.

- The highest BCF reported in the literature for the particular species of interest was selected for use in this assessment.

Wildlife exposures to chemicals in food are evaluated only for chemicals with BCFs greater than 300. As discussed in Chapter 4, BCFs greater than 300 generally are considered to result in significant bioaccumulation in aquatic life (EPA 1989b). As a result, wildlife food exposures are not evaluated for any volatile organic chemical or for thiodiglycol, methylphosphonic acid, 1,4-dithiane, or 1,3-dinitrobenzene, as these chemicals do not, or are not expected to, bioaccumulate appreciably in aquatic life.

Once BCFs have been selected, chemical concentrations in food were estimated using the selected BCF and the measured surface water concentrations in an equilibrium partitioning model:

$$C_f = (C_w * BCF) \qquad \text{(Eq. 5)}$$

where

C_f = chemical concentration in food (mg/kg);

C_w = chemical concentration in the water column (mg/L); and

$BCF_{f:w}$ = food:water BCF (mg/kg food per mg/L water).

For chemical concentrations in water, the total chemical concentration was used because information on dissolved concentrations in Watson Creek is not available. This resulted in overestimates of exposure because chemicals sorbed onto particles are not available for uptake through the gills. The

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[7] The principal exceptions to this are highly hydrophobic organic compounds such as PCBs, dioxins, and DDT.

RME concentrations reported in Table 5-28 were used to estimate concentrations in Watson Creek aquatic life.

Wildlife exposures via ingestion of contaminated food were estimated using the following equation:

$$Dose = C_f * FI_f/BW \qquad \text{(Eq. 6)}$$

where

Dose = exposure (mg/kg bw);

C_f = concentration in food (mg chemical/kg food);

FI_f = daily food intake by wildlife of contaminated aquatic life from Watson Creek (kg); and

BW = body weight (kg).

Quantitative estimates of exposure are provided below for great blue heron, spotted sandpiper, and muskrat.

5.4.2.2.1 Estimates of Exposures in Great Blue Heron

Great blue heron are likely to feed in the marshes and surface waters of Watson Creek. This species feeds almost exclusively on aquatic life, with fish being the principal component of the diet. A variety of other aquatic species, including amphibians, reptiles, insects, and crustaceans typically comprise a small portion of the diet. Heron exposures to chemicals that have accumulated in fish are evaluated in this assessment.

In selecting fish:water BCFs for use in this risk assessment, the following screening procedures were used in addition to those identified above.

- BCFs for species potentially occurring in Watson Creek (see Section 5.4.1) were used when available. Information on species that are possible residents of Watson Creek was used over information for species that would use Watson Creek intermittently, because resident species would have a greater exposure duration and, therefore, potentially greater tissue concentrations of chemicals of potential concern.

- The highest BCF reported in the literature for Watson Creek species was selected for use in this assessment. If no BCF was available for species potentially present in Watson Creek, the highest BCF reported for either freshwater or marine species was selected for use.

Fish:water BCFs are presented in Table 5-29 for the chemicals being evaluated for this exposure pathways. No BCFs are presented for antimony, arsenic, copper, fluoride, and zinc, as these chemicals of potential concern have fish:water BCFs of 20 or less. No BCFs are presented for sulfate, iron, and boron due to lack of data on bioaccumulation of these chemicals. Because of their physicochemical properties, however, none of these chemicals is expected to accumulate appreciably in aquatic life. No BCF was found in the literature for di-n-octylphthalate, so bioaccumulation was not evaluated for this chemical. Based on physicochemical properties alone this chemical could

TABLE 5-28

EXPOSURE CONCENTRATIONS FOR BENTHIC SPECIES LIVING WITHIN THE GROUNDWATER DISCHARGE ZONE IN WATSON CREEK

(Concentrations reported in ug/L)

	Concentration in Groundwater Near Watson Creek (b)			
Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (c)	Maximum Detected Concentration	RME Concentration for Benthic Exposures (d)
Benzene (C6H6)	200	4.4E+08	1,110	1,110
Carbon Tetrachloride (CCL4)	48	3,700	378	378
Chlorobenzene (CLC6H5)	42	1.4E+06	156	156
Chloroform (CHCL3)	300	1.1E+09	1,820	1,820
1,2-Dichloroethane (12DCLE)	190	3.5E+07	1,100	1,100
1,2-Dichloroethene [Total] (12DCE)	600	8.2E+07	2,260	2,260
1,3-Dinitrobenzene (13DNB)	24	1.7E+15	71.8	71.8
1,4-Dithiane (DITH)	150	960,000	595	595
Methylene Chloride (CH2CL2)	68	150,000	228	228
Methylphosphonic Acid (MPA)	1,600	24,000	10,000	10,000
1,1,2,2-Tetrachloroethane (TCLEA)	690	2.7E+08	3,200	3,200
Tetrachloroethene (TCLEE)	94	960,000	392	392
Thiodiglycol (TDGCL)	31,000	1.4E+08	200,000	200,000
Toluene (MEC6H5)	13	23,000	57	57
1,1,2-Trichloroethane (112TCE)	28	930	219	219
Trichloroethene (TRCLE)	530	3.2E+08	3,430	3,430
Vinyl Chloride (C2H3CL)	200	1.2E+07	1,430	1,430

(a) USATHAMA chemical codes listed in parentheses.
(b) For wells 14A, 14B, 14C, 20A, 20B, 21, 22, 22A, and 22B.
(c) Values reflect a positively skewed distribution.
(d) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

TABLE 5-29

FISH BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF HERON EXPOSURES TO CHEMICALS IN WATSON CREEK SURFACE WATER

Chemical (a)	BCF	Basis	Reference
Cadmium	7,440	26-week, whole body bioconcentration in mosquito fish	Giesy et al. (1977) in Eisler (1985)
Manganese	560 (b)	Field study of bioconcentration/bio-accumulation in African marine fish	Van As et al. (1973) in AQUIRE (1990)
Mercury	85,700	75-day, whole body bioconcentration in rainbow trout (Salmo gairdneri)	Niimi and Lowe-Jinde (1984) in EPA (1985b)
Selenium	470	120-day, whole body bioconcentration in blue gill (Lepomis macrochirus)	Lemly (1982) in EPA (1987b)

(a) Only chemicals of potential concern with measured BCFs greater than 300 are listed here. See text for rationale.
(b) Bioaccumulation factor (BAF), which takes into account accumulation from food as well as water.

bioaccumulate significantly in fish. However, given the limited distribution of this chemical in Watson Creek surface water (1/20 samples) and its relatively low concentration (8 µg/L), it is unlikely to contribute significantly to exposures in herons. Furthermore, di-n-octylphthalate is probably present on suspended sediments in surface water, and therefore would not be available for uptake.

Concentrations of chemicals in fish were estimated by using the selected fish:water BCF and the measured surface water concentrations in the equilibrium partitioning model presented in Equation 5 above. Heron exposures via ingestion of fish were estimated using Equation 6 above. For this assessment, heron were assumed to weigh 3.6 kg and ingest 134 g (0.134 kg) of food each day, of which 70% (94 g) is fish (see Appendix D for the source of these values). Heron are further assumed to obtain 10% of their daily fish intake, or 9.4 g (0.0094 kg), from Watson Creek. This is a reasonable and perhaps conservative assumption given the wide availability of suitable heron habitat in the areas surrounding O-Field and the fact that heron forage over a several square mile area (see Appendix D).

The resulting estimates of exposure are presented in Table 5-30.

5.4.2.2.2 Estimates of Exposures in Spotted Sandpiper

Spotted sandpiper are likely to feed in the marshes and shoreline of Watson Creek. This species is an insectivore and feeds predominantly on sediment-dwelling invertebrates. Insects are the principal component of the diet, although marine worms, small crustaceans, and small mollusks also may be eaten. This assessment evaluates sandpiper exposure via ingestion of aquatic insects that have accumulated chemicals from Watson Creek.

Chemical concentrations in insects were estimated using the BCF approach outlined above. BCFs for insects were obtained from the available literature, and the highest reported BCF was selected as for use in calculating sandpiper exposure. If no BCF was reported for insects, the highest BCF for marine worms, small crustaceans, or small mollusks was selected for use. Insect:water BCFs for cadmium, manganese, mercury, selenium, and zinc are presented in Table 5-31. For reasons similar to those stated above under heron exposures, no BCFs are presented for the other chemicals of potential concern in surface water.

Concentrations of chemicals in insects were estimated by Equation 5 above and the selected insect:water BCF. Again, total chemical concentrations in water were used to estimate insect chemical concentrations, because no information is available on dissolved chemical concentrations in Watson Creek. As discussed above, this resulted in overestimates of exposure, because chemicals sorbed onto particles are not available for uptake. The RME concentrations reported in Table 5-26 are used to estimate concentrations in Watson Creek insects. Concentrations averaged over all of Watson Creek are not necessarily representative of concentrations in the areas where sandpipers could be exposed, given that sandpipers are likely to forage only in the marshes and shoreline surrounding Watson Creek and not in the main body of the Creek. However, because there appears to be no clear difference in the distribution of the selected inorganic chemicals in the marsh/shoreline or creek body, concentrations averaged across the creek are regarded here as reasonably representative of concentrations in the areas where sandpipers may forage. The estimated concentrations in insects are presented in Table 5-32.

Sandpiper exposures were estimated using Equation 6. For this assessment, sandpipers were assumed to weigh 43 g (0.043 kg) and ingest 7.5 g (0.0075 kg) of food each day, all of which was assumed to be insects (see Appendix D for source of values). Sandpipers were further assumed to obtain 50% of their daily insect intake, or 3.8 g, from Watson Creek. This is a reasonable and probably conservative assumption given the wide availability of suitable sandpiper habitat in the areas

TABLE 5-30

ESTIMATED EXPOSURES IN HERON INGESTING FISH THAT HAVE ACCUMULATED CHEMICALS FROM WATSON CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg fish per mg/L water) (b)	Estimated Concentration in Fish (mg/kg fish)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0025	7,440	19	0.05
Manganese	0.75	560	420	1.1
Mercury	0.0003	85,700	26	0.07
Selenium	0.069	470	32	0.08

(a) Reported previously in Table 5-26.
(b) Reported previously in Table 5-29.
(c) Calculated assuming a heron weighs 3.6 kg and ingests 9.4 g (0.0094 kg) of fish from Watson Creek each day.

TABLE 5-31

INVERTEBRATE BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF SANDPIPER EXPOSURES TO CHEMICALS IN WATSON CREEK SURFACE WATER

Chemical (a)	BCF	Basis	Reference
Cadmium	4,190	28-day, bioconcentration in the caddisfly (Hydropsyche betteni)	Spehar et al. (1978) in EPA (1985c)
Manganese	3,900	Chironomid larvae	Salanki et al. (1982) in AQUIRE (1990)
Mercury	24,000	21-day, bioconcentration in clodoceran (Daphnia magna) (b)	Biesinger et al. (1982)
Selenium	1,100	28-day, bioconcentration in daphnids exposed to selenium (IV) in a laboratory closed-system microcosm study (b)	Besser et al. (1989)
Zinc	1,130	14-day, bioconcentration in mayfly (Ephemerella grandis)	Nehring (1976) in EPA (1987c)

(a) Only chemicals of potential concern with measured BCFs greater than 300 are listed here. See text for rationale.

(b) Daphnia are small crustaceans. This information is presented here in the absence of information on bioaccumulation in insects.

TABLE 5-32

ESTIMATED EXPOSURES IN SANDPIPERS INGESTING INSECTS THAT HAVE ACCUMULATED CHEMICALS FROM WATSON CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg insect per mg/L water) (b)	Estimated Concentration in Insects (mg/kg insect)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0025	4,190	10	0.88
Manganese	0.75	3,900	2,900	260
Mercury	0.0003	24,000	7.2	0.64
Selenium	0.069	1,100	76	6.7
Zinc	0.041	1,130	46	4.1

(a) Reported previously in Table 5-26.
(b) Reported previously in Table 5-31.
(c) Calculated assuming a sandpiper weighs 43 g (0.043 kg) and ingests 3.8 g (0.0038 kg) of insects from Watson Creek each day.

surrounding O-Field and the fact that sandpipers consume flying (adult) insects in addition to aquatic larvae.

The resulting estimates of exposure are presented in Table 5-32.

5.4.2.2.3 Estimates of Exposures in Muskrat

Muskrat are likely to feed in Watson Creek and the surrounding marshes. This species is an aquatic herbivore and feeds predominantly on shoots, roots, tubers, stems and leaves of aquatic macrophytes. In Maryland marshes, rushes (*Scirpus* spp.) and cattail (*Typha* spp.) comprise an estimated 80% of the diet of muskrat (see Appendix D). This assessment evaluates muskrat exposure via ingestion of aquatic macrophytes that have accumulated chemicals from Watson Creek.

Chemical concentration in macrophytes were estimated using the BCF approach outlined above. BCFs for aquatic macrophytes were obtained from the available literature, and the highest reported BCF was selected as for use in calculating muskrat exposure. Plant:water BCFs for cadmium and selenium were presented in Table 5-33. For reasons similar to those stated previously, no BCFs are presented for the other chemicals of potential concern in surface water.

Concentrations of chemicals in plants were estimated by inputting the selected plant:water BCF and the measured surface water concentrations into Equation 5. The RME concentrations reported in Table 5-26 were used to estimate concentrations in Watson Creek macrophytes. The estimated concentrations in plants are presented in Table 5-34.

Muskrat exposures were estimated using Equation 6. For this assessment, muskrat were assumed to weigh 1.35 kg and ingest 110 g (0.110 kg) of food each day, all of which was assumed to be aquatic macrophytes (see Appendix D for source of values). Muskrat were further assumed to obtain all of their daily food intake from Watson Creek. This is a reasonable assumption because muskrats tend to have small foraging areas, typically foraging within 30 to 50 feet of their homes (see Appendix D).

The resulting estimates of exposure are presented in Table 5-34.

5.4.3 TOXICITY ASSESSMENT

The general methodology for the development of toxicity values for the evaluation of ecological impacts is described in Chapter 4. The toxicity values to be used to evaluate aquatic life and terrestrial wildlife impacts are presented in this section along with a brief description of the basis of each value. Tables 5-35 and 5-36 present acute and chronic toxicity values for the assessment of aquatic life impacts from exposure to chemicals of potential concern in surface water. Table 5-37 presents toxicity values for the assessment of aquatic life impacts from exposure to chemicals in sediment. Finally, Table 5-38 presents toxicity values for the assessment of impacts in terrestrial wildlife feeding at O-Field. Appendix C presents complete ecological toxicity summaries for all chemicals of potential concern for which exposures are being evaluated.

5.4.4 ESTIMATES OF IMPACT

Impacts to aquatic and terrestrial wildlife exposed to chemicals of potential concern at O-Field were evaluated by comparing estimated exposures with the appropriate toxicity value for the chemical and receptors of concern. Exposures that exceed the selected toxicity value suggest that impacts may be

TABLE 5-33

PLANT BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF MUSKRAT EXPOSURES TO CHEMICALS IN WATSON CREEK SURFACE WATER THAT HAVE ACCUMULATED IN AQUATIC MACROPHYTES

Chemical (a)	BCF	Basis	Reference
Cadmium	960	Bioconcentration in aquatic ferns (Salvinia natans)	EPA (1985c)
Selenium	363	28-day, bioconcentration in aquatic macrophytes exposed to selenium (IV) in a closed-system microcosm study	Besser et al. (1989)

(a) Only chemicals of potential concern with meausred BCFs greater than 300 are listed here. See text for rationale.

TABLE 5-34

ESTIMATED EXPOSURES IN MUSKRATS INGESTING AQUATIC MACROPHYTES THAT HAVE ACCUMULATED CHEMICALS FROM WATSON CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg plant per mg/L water) (b)	Estimated Concentration in Plants (mg/kg plant)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0025	960	2.4	0.20
Selenium	0.069	363	25	2.0

(a) Reported previously in Table 5-26.
(b) Reported previously in Table 5-33.
(c) Calculated assuming a muskrat weighs 1.35 kg and ingests 110 g (0.110 kg) of plants from Watson Creek each day.

TABLE 5-35

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT O-FIELD

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Benzene (C6H6)	1,630	24-hour LC50 in brine shrimp	Abernethy et al. (1986) in AQUIRE (1990)
Carbon Tetrachloride (CCL4)	2,700	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
Chlorobenzene (CLC6H5)	4,700	96-hour LC50 in rainbow trout	Dalich et al. (1982)
Chloroform (CHCL3)	17,900	96-hour LC50 in bluegill	Anderson and Lusty (1980) in AQUIRE (1990)
1,2-Dichloroethane (12DCLE)	1,800	LC50 in orfe	Knie et al. (1983) in AQUIRE (1990)
1,2-Dichloroethene (12DCE)	22,000	48-hour LC50 in Daphnia; factor of 10 applied to account for interspecies variation	LeBlanc (1980)
1,3-Dinitrobenzene (13DNB)	500	96-hour LC50 in fathead minnows; factor of 10 applied to account for interspecies variation	AQUIRE (1990)
Di-n-octylphthalate (DNOP)	--	--	--
1,4-Dithiane (DITH)	26,500	96-hour LC50 in sheepshead minnow estimated based on SAR	See Appendix C for derivation
bis(2-Ethylhexyl)phthlate (B2EHP)	133	48-hour EC50 in Daphnia magna	Passino and Smith (1987)
Methylene Chloride (CH2CL2)	22,000	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
Methylphosphonic Acid (MPA)	--	--	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	48-hour LC50 in Daphnia; factor of 10 applied to account for interspecies variation	LeBlanc (1980)
Tetrachloroethene (TCLEE)	1,300	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
Thiodiglycol (TDGCL)	684,000	96-hour LC50 in sheepshead minnow estimated based on SAR	See Appendix C for derivation

See footnotes on the following page.

TABLE 5-35 (Continued)

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT O-FIELD

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Toluene (MEC6H5)	641	24-hour LC50 in brine shrimp	Abernethy et al. (1986) in AQUIRE (1990)
1,1,2-Trichloroethane (112TCE)	19,000	96-hour LC50 in saltwater fish estimated based on SAR	See Appendix C for derivation
Trichloroethene (TRCLE)	18,000	48-hour LC50 in Daphnia	LeBlanc (1980)
Vinyl Chloride (C2H3CL)	28,000	96-hour LC50 in saltwater fish estimated based on SAR	See Appendix C for derivation
Inorganic Chemicals:			
Antimony (SB)	88	Proposed AWQC (freshwater)	EPA (1988)
Arsenic [III] (ASIII)	69	AWQC (saltwater)	EPA (1986)
Arsenic [V] (ASV)	850	LOEC in freshwater species	EPA (1985d)
Boron (B)	12,000	LC50 in salmon	Eisler (1990)
Cadmium (CD)	43	AWQC (saltwater)	EPA (1985c)
Copper (CU)	2.9	AWQC (saltwater)	EPA (1985e)
Fluoride (F)	2,700	48-hour LC50 in rainbow trout	Neuhold and Sigler (1960)
Iron (FE)	320	96-hour LC50 in aquatic insects	Warnick and Bell (1969) in EPA (1976)
Manganese (MN)	1,450	96-hour LC50 in rainbow trout	Davies (1980)
Mercury (HG)	2.2	LOEC for acute toxicity in freshwater invertebrates	EPA (1985b)
Selenium (SE)	20	AWQC (freshwater)	EPA (1987b)
Sulfate (SO4)	190,000	LC50 in diatoms; factor of 10 applied to account for interspecies variation	Patrick et al. (1968)
Zinc (ZN)	95	AWQC (saltwater)	EPA (1987c)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.

-- = No information available.

AWQC = Ambient Water Quality Criteria.
LOEC = Lowest-observed-effect concentration.
SAR = Structure activity relationships.

TABLE 5-36

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT O-FIELD

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Benzene (C6H6)	8,640	LC50 in ELS test with rainbow trout	Black et al. (1982) in AQUIRE (1990)
Carbon Tetrachloride (CCL4)	6,710	14-day LC50 in guppies; factor of 10 applied to account for interspecies variation	Koneman (1981) in AQUIRE (1990)
Chlorobenzene (CLC6H5)	210	30-day LOEC in rainbow trout; factor of 10 applied to account for interspecies variation	Dalich et al. (1982) in AQUIRE (1990)
Chloroform (CHCL3)	124	28-day LC50 in ELS test with rainbow trout	Black and Birge (1980) in AQUIRE (1990)
1,2-Dichloroethane (12DCLE)	34	28-day LC50 in rainbow trout	Black et al. (1982) in AQUIRE (1990)
1,2-Dichloroethene (12DCE)	8,800	Estimated chronic value; extrapolated from acute LC50 in Daphnia by applying an ACR of 25	LeBlanc (1980)
1,3-Dinitrobenzene (13DNB)	17	8-day LOEC in blue green algae; factor of 10 applied to account for interspecies variation	Bringmann and Kuhn (1978) in AQUIRE (1990)
Di-n-octylphthalate (DNOP)	32	15-day NOEC in Daphnia magna based on reproductive effects; factor of 10 applied to account for interspecies variation	McCarthy and Whitmore (1985)
1,4-Dithiane (DITH)	21,900	14-day LC50 in fish estimated based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation
bis(2-Ethylhexyl)phthlate (B2EHP)	360	Proposed AWQC (freshwater)	EPA (1987d)
Methylene Chloride (CH2CL2)	29,400	14-day LC50 in guppies; factor of 10 applied to account for interspecies variation	Koneman (1981) in AQUIRE (1990)
Methylphosphonic Acid (MPA)	--	--	--
1,1,2,2-Tetrachloroethane (TCLEA)	690	28-day LOEC based on reproductive effects in Daphnia; factor of 10 applied to account for interspecies variation	Richter et al. (1983) in AQUIRE (1990)

See footnotes at the end of table.

TABLE 5-36 (Continued)

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT O-FIELD

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Tetrachloroethene (TCLEE)	520	Estimated chronic value; extrapolated from acute LC50 in bluegill by applying an ACR of 25	Buccafusco et al. (1981)
Thiodiglycol (TDGCL)	1,060,000	14-day LC50 in fish estimated based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation
Toluene (MEC6H5)	25	LC50 in ELS tests with rainbow trout	Black et al. (1982) in AQUIRE (1990)
1,1,2-Trichloroethane (112TCE)	13,300	7-day LC50 in guppies; factor of 10 applied to account for interspecies variation; data for 1,1,1-trichloroethane	Koneman (1981) in AQUIRE (1990)
Trichloroethene (TRCLE)	720	Estimated chronic value; extrapolated from LC50 in Daphnia by applying an ACR of 25	LeBlanc (1980)
Vinyl Chloride (C2H3CL)	28,000	14-day LC50 estimated for fish based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation
[illegible]organic Chemicals:			
Antimony (SB)	30	Proposed AWQC (freshwater)	EPA (1988)
Arsenic [III] (ASIII)	36	AWQC (saltwater)	EPA (1985d)
Arsenic [V] (ASV)	13	LOEC for saltwater species	EPA (1985d)
Boron (B)	6,400	MATC in cladocerans	Eisler (1990)
Cadmium (CD)	9.3	AWQC (saltwater)	EPA (1985c)
Copper (CU)	2.9	AWQC (saltwater)	EPA (1985e)
Fluoride (F)	1,500	Delayed hatching in rainbow trout eggs exposed for 7-10 days	Ellis et al. (1948)
Iron (FE)	1,000	AWQC (freshwater)	EPA (1986)
Manganese (MN)	10	Growth reduction in Pacific oyster larvae exposed for 14-days	Watling (1983) in AQUIRE (1990)

See footnotes on the following page.

TABLE 5-36 (Continued)

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT O-FIELD

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Inorganic Chemicals (cont.):			
Mercury (HG)	0.26	Chronic value for fathead minnow	EPA (1985b)
Selenium (SE)	5	AWQC (freshwater)	EPA (1987b)
Sulfate (SO4)	76,000	Estimated chronic value; extrapolated from an LC50 in diatoms by applying an ACR of 25	Patrick et al. (1968)
Zinc (ZN)	86	AWQC (saltwater)	EPA (1987c)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.

-- = No information available.
ACR = Acute to chronic ratio.
AWQC = Ambient water quality criterion.
ELS = Early lifestage.
LOEC = Lowest-observed-effect concentration.
MATC = Maximum acceptable toxicant concentration.
SAR = Structure activity relationships.

TABLE 5-37

TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SEDIMENT AT O-FIELD

Chemical (a)	Sediment Toxicity Value (mg/kg)	Basis for Value (b)	Reference
Organic Chemicals:			
PAHs	2.0	Reported 10-day LC50 in Rhepoxynius abronius (an amphipod)	Chapman et al. (1987)
Phthalates:			
Di-n-butylphthalate (DNBP)	10	NOEC based on studies with grass shrimp	Clark et al. (1987)
bis(2-Ethylhexyl)phthalate (B2EHP)	--	--	--
Diethylphthalate (DEP)	5.3	Concentration at or above level at which significant biological effects will occur; based on studies with oysters	Barrick and Beller (1989)
Dimethylphthalate (DMP)	22	Concentration at or above level at which significant biological effects will occur; based on studies with oysters	Barrick and Beller (1989)
Inorganic Chemicals:			
Ammonia (NH3)	--	--	--
Antimony (SB)	150	Concentration at or above level at which significant biological effects will occur; based on benthic studies in Puget Sound	Barrick and Beller (1989)
Beryllium (BE)	--	--	--
Boron (B)	--	--	--
Copper (CU)	390	Concentration at or above level at which significant biological effects will occur; based on sediment toxicity studies with oysters	Barrick and Beller (1989)
Mercury (HG)	0.8	Estimated threshold concentration based on early lifestage tests in rainbow trout	Birge et al. (1977) in Birge et al. (1987)
Nitrite (NO2)	--	--	--
Thallium (TL)	--	--	--
Zinc (ZN)	760	Estimated threshold concentration based on early lifestage tests in rainbow trout	Birge et al. (1977) in Birge et al. (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) See Appendix C for more study details.
-- = No information available.

TABLE 5-38

TOXICITY VALUES FOR ASSESSMENT OF TERRESTRIAL WILDLIFE IMPACTS FROM EXPOSURE TO CHEMICALS AT O-FIELD

		Basis for Value (c)					
Receptor Species/ Chemical (a)	Toxicity Value (mg/kg bw) (b)	Test Species	Exposure Duration	Dose (mg/kg bw)	Effect	Source	Uncertainty Factor
Heron and Sandpiper:							
Cadmium (CD)	0.13	Poultry	Not reported	12.5 (d)	Reduced egg fertility and hatchability	Puls (1988)	100 (to account for interspecies differences and to extrapolate a NOAEL from an effect level)
Manganese (MN)	51	Turkey	21 Days	510 (d)	NOAEL; decreased growth	Vohra and Kratzer (1968) in NAS (1980)	10 (to account for interspecies variation)
Mercury (HG)	0.41	Chicken, turkey, pheasant, duck	Not reported	0.41 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)
Selenium (SE)	0.38 (sandpiper)	Stilt, avocet	2 Years	3.8 (e)	Reduced survival in young	Williams et al. (1989)	10 (to extrapolate a NOAEL from a LOAEL)
	0.61 (heron)	Black-crowned night heron	92 Days	0.61 (e)	NOAEL; egg hatching	Smith et al. (1988)	None (NOAEL from a taxonomically similar species)
Zinc (ZN)	7.8	Japanese quail	2 Weeks	7.8 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)
Muskrat:							
Cadmium (CD)	0.015	Domestic mammals	Recommended for long-term exposure	0.015 (d)	Recommended safe level	NAS (1980)	None (value derived to protect a variety of domestic mammals)
Selenium (SE)	0.06	Domestic mammals	Recommended for long-term exposure	0.06 (d)	Recommended safe level	NAS (1980)	None (value derived to protect a variety of domestic mammals)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using methodology outlined in Chapter 4.
(c) See Appendix C for additional information on the referenced studies.
(d) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages using the dietary conversion factors reported in Lehman (1954). See Appendix C for more detail.
(e) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages based on average body weights in tested species and estimated food intake rates. See Appendix C for more detail.

possible in the evaluation species or similar species. Potential impacts to aquatic life are discussed below in Section 5.4.4.1, and those to terrestrial wildlife are discussed in Section 5.4.4.2.

5.4.4.1 Potential Impacts in Aquatic Life

Aquatic life exposures to chemicals in Watson Creek and Gunpowder River surface water and sediment were evaluated. Potential impacts are discussed separately below.

5.4.4.1.1 Surface Water

Surface water exposures were evaluated both for water column species and for benthic species living within the groundwater discharge zone in Watson Creek. Tables 5-39 and 5-40 present a comparison of measured and estimated surface water concentrations in Watson Creek and the Gunpowder River with the selected acute and chronic toxicity values. As the comparisons indicate, surface water concentrations of several chemicals exceed acute and/or chronic toxicity values for aquatic life. For water-column exposures, inorganic chemicals are the only chemicals that exceed toxicity values; antimony, arsenic, manganese, mercury, selenium, and sulfate concentrations in both Watson Creek and the Gunpowder River were elevated above acute and/or chronic toxicity values. However, the estimated organic chemical concentrations in sediment pore water within the groundwater discharge zone are significantly higher than those in other parts of Watson Creek, and the chronic toxicity values for several chemicals are exceeded, as is the acute toxicity value for 1,1,2,2-tetrachloroethane. Judging from these comparisons, benthic species living within the groundwater discharge zone in Watson Creek are probably being impacted from organic contamination to a greater degree than species that occur principally in the water column within this area or in other areas of the creek.

Evaluation of potential aquatic life impacts on a chemical-specific basis ignores the potential toxicity associated with the chemical mixture. Chemicals may act additively, synergistically, antagonistically, or not at all, but usually too few data are available to quantify chemical interactions within mixtures. In the absence of precise information on chemical interactions, a simplistic approach to evaluating chemical mixture toxicity is to assume additivity of effects. Such an assumption may be valid, particularly when all the chemicals under consideration induce toxic effects via the same mechanism of action. There is a large body of literature that shows that the mechanism by which many non-ionizable, industrial organic chemicals (such as the organic chemicals of concern in Watson Creek) induce acute toxicity in aquatic organisms is via a nonspecific narcotic or anesthetic mode of action. Abernathy et al. (1988) investigated this narcotic mode of action in aquatic organisms and found a correlation between narcotic effects and the volume fraction of the toxicant at the target site (nerve cell membrane). They hypothesized that the narcotic effect occurs when the sum of the individual chemical volume fractions equals or exceeds a critical volume. Further, they suggested that because of this mode of action, the toxicity of the mixture is related to the toxicity of the individual chemicals of equal molar volume as follows:

$$\frac{1}{LC50_{mix}} = \sum_{i=1}^{N} \frac{C_i}{LC50_i} \qquad \text{(Eq. 7)}$$

where

C_i = the concentration of each component of the mixture containing N components.

TABLE 5-39

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN WATSON CREEK AND GUNPOWDER RIVER SURFACE WATER

(Concentrations reported in ug/L)

Chemical (a)	Toxicity Value (b)		Exposure Concentration (c)	Toxicity Value Exceeded
	Acute	Chronic		
WATSON CREEK				
Organic Chemicals:				
Benzene (C6H6)	1,630	8,640	18.4 (d)	--
Carbon Tetrachloride (CCL4)	2,700	6,710	5.79 (d)	--
Chlorobenzene (CLC6H5)	4,700	210	4.78 (d)	--
Chloroform (CHCL3)	17,900	124	35.2 (d)	--
1,2-Dichloroethane (12DCLE)	1,800	34	22.6 (d)	--
1,2-Dichloroethene (12DCE)	22,000	8,800	59 (d)	--
1,3-Dinitrobenzene (13DNB)	500	17	10 (d)	--
1,4-Dithiane (DITH)	26,500	21,900	63 (e)	--
Methylene Chloride (CH2CL2)	22,000	29,400	6.9 (d)	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	690	121 (d)	--
Tetrachloroethene (TCLEE)	1,300	520	11.7 (d)	--
Thiodiglycol (TDGCL)	684,000	1,060,000	13,000 (e)	--
Toluene (MEC6H5)	641	25	1.17 (d)	--
1,1,2-Trichloroethane (112TCE)	19,000	13,300	3.81 (d)	--
Trichloroethene (TRCLE)	18,000	720	60.2 (d)	--
Vinyl Chloride (C2H3CL)	28,000	28,000	15.8 (d)	--
Inorganic Chemicals:				
Antimony (SB)	88	30	149	Acute, Chronic
Arsenic [III] (ASIII)	69	36	71	Acute, Chronic
Arsenic [V] (ASV)	850	13	63	Chronic
Boron (B)	12,000	6,400	530	--
Cadmium (CD)	43	9.3	3	--
Copper (CU)	2.9	2.9	2	--
Fluoride (F)	2,700	1,500	350	--
Iron (FE)	320	1,000	440	--
Manganese (MN)	1,450	10	750	Chronic
Mercury (HG)	2.2	0.26	0.3	Chronic
Selenium (SE)	20	5	69	Acute, Chronic
Sulfate (SO4)	190,000	76,000	690,000	Acute, Chronic
Zinc (ZN)	95	86	41	--
GUNPOWDER RIVER				
Organic Chemicals:				
bis(2-Ethylhexyl)phthalate (B2EHP)	133	360	24	--
Inorganic Chemicals:				
Antimony (SB)	88	30	126	Acute, Chronic
Arsenic [III] (ASIII)	69	36	75	Acute, Chronic
Arsenic [V] (ASV)	850	13	15	Chronic
Boron (B)	12,000	6,400	1,020	--
Manganese (MN)	1,450	10	562	Chronic
Selenium (SE)	20	5	53	Acute, Chronic
Sulfate (SO4)	190,000	76,000	473,000	Acute, Chronic

(a) USATHAMA chemical codes listed in parentheses. Only chemicals with toxicity values are listed. The following chemicals are not presented due to lack of toxicity criteria: di-n-octylphthalate and methylphosphonic acid.
(b) Reported previously in Tables 5-35 and 5-36.
(c) Reported previously in Table 5-26. Based on measured concentrations, except as noted.
(d) For all chemicals except where noted, the value is the high estimate average surface water concentration, reported previously in Table 5-16.
(e) High estimate initial surface water concentration, reported previously in Table 5-16.

-- = No toxicity value exceeded.

TABLE 5-40

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH ESTIMATED CONCENTRATIONS IN SEDIMENT PORE WATER IN THE WATSON CREEK GROUNDWATER DISCHARGE ZONE

(Concentrations reported in ug/L)

Chemical (a)	Toxicity Value (b)		Exposure Concentration (c)	Toxicity Value Exceeded
	Acute	Chronic		
Benzene (C6H6)	1,630	8,640	1,110	--
Carbon Tetrachloride (CCL4)	2,700	6,710	378	--
Chlorobenzene (CLC6H5)	4,700	210	156	--
Chloroform (CHCL3)	17,900	124	1,820	Chronic
1,2-Dichloroethane (12DCLE)	1,800	34	1,100	Chronic
1,2-Dichloroethene (12DCE)	22,000	8,800	2,260	--
1,3-Dinitrobenzene (13DNB)	500	17	71.8	Chronic
1,4-Dithiane (DITH)	26,500	21,900	595	--
Methylene Chloride (CH2CL2)	22,000	29,400	10,000	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	690	3,200	Acute, Chronic
Tetrachloroethene (TCLEE)	1,300	520	392	--
Thiodiglycol (TDGCL)	684,000	1,060,000	200,000	--
Toluene (MEC6H5)	641	25	57	Chronic
1,1,2-Trichloroethane (112TCE)	19,000	13,300	219	--
Trichloroethene (TRCLE)	18,000	720	3,430	Chronic
Vinyl Chloride (C2H3CL)	28,000	28,000	1,430	--

(a) USATHAMA chemical codes listed in parentheses. Only chemicals with toxicity values are listed. The following chemical is not presented due to lack of toxicity criteria: methylphosphonic acid.
(b) Reported previously in Tables 5-35 and 5-36.
(c) Reported previously in Table 5-28. Estimated concentrations.

-- = No toxicity value exceeded.

This approach was used here to evaluate the acute toxicity of the organic chemicals of concern in Watson Creek by comparing the LC_{50} of the mixture to the sum of the exposure concentrations for all organic chemicals present in the water column and in the sediment pore water. Using this approach, the estimated $LC50_{mix}$ and total exposure concentrations (C_{tot}) are as follows:

- Water-column: $LC50_{mix}$ = 2 µg/L
  C_{tot} = 14,300 µg/L;
- Sediment-pore water: $LC50_{mix}$ = 0.15 µg/L
  C_{tot} = 226,000 µg/L.

Thus, when the additivity of toxic effects was considered, organic chemical concentrations in Watson creek surface water and sediment pore water in the groundwater discharge zone were estimated to be highly acutely toxic to aquatic life.

All of the above comparisons suggest that aquatic life in Watson Creek and the Gunpowder River are being impacted by chemical contaminants associated with O-Field. Impacts in Watson Creek are likely more severe than those in the Gunpowder River, given the greater number of chemicals at higher concentrations in the creek. Also, the more closed nature of Watson Creek relative to the Gunpowder River probably makes it more susceptible to impacts than the river. Impacts associated with organic contaminants in Watson Creek are probably localized to the area of groundwater discharge, which is likely to have the highest concentrations of volatile organic chemicals being released to surface water. Impacts associated with inorganic contaminants are probably more widespread, given the relatively even distribution of these chemicals throughout the creek.

Acute and chronic toxicity in O-Field surface waters have probably affected the composition and structure of the aquatic communities in Watson Creek and possibly the Gunpowder River near O-Field. Although it is difficult to predict the exact nature of such impacts, chemical toxicity may have resulted in a decrease in species diversity and species numbers, as species more tolerant of highly contaminated waters compete against less tolerant species. Localized reductions in species diversity and number are possible in the groundwater discharge zone area, as this area is subject to the release of significantly higher organic chemical concentrations from groundwater.

It also is possible that chemical contaminants in Watson Creek are impacting nonresident species that use the area seasonally or occasionally. For example, Watson Creek probably serves as a nursery area for blueback herring, bay anchovy, and menhaden. Larvae and juveniles of these species could experience reductions in survival and growth as a result of exposure to chemicals in Watson Creek. Because Watson Creek is likely to provide nursery habitat for, at most, only a small proportion of the total population of herring, anchovy, and menhaden in the Chesapeake Bay, these effects are unlikely to have significant impacts on the entire populations of these species. However, they could result in localized reductions in population size and could contribute to cumulative impacts associated with APG as a whole (see Chapter 13).

These estimates of impact do not include potential effects of exposure to any of the TICs in groundwater that are potentially being discharged to surface water or to any of the other chemicals listed in Table 5-13 that are potentially present in groundwater and potentially released to surface water (e.g., agent breakdown products, munitions compounds, ammonia). Exposure to these other compounds could add significantly to estimates of aquatic life impact.

5.4.4.1.2 Sediment

Table 5-41 presents a comparison of sediment exposure concentrations in Watson Creek aquatic life toxicity values. No toxicity values are exceeded, suggesting that aquatic life impacts from exposure to chemicals in sediment are not likely. However, the sediment toxicity values were derived from a very limited toxicity database and therefore may not be protective of aquatic life in Watson Creek.

Aquatic life may be exposed to other compounds in sediment in addition to those measured. For example, white phosphorus can exist in pure form in anaerobic sediments, and, according to historical information, could be present in Watson Creek sediments. White phosphorus is very toxic to aquatic life (see Appendix C) and if released from sediments (e.g., during a storm event) could result in additional impacts to aquatic life. Other chemicals potentially present in sediment but not analyzed for in sediments, could result in aquatic life impacts (e.g., agent breakdown products, munitions compounds).

5.4.4.2 Potential Impacts in Terrestrial Wildlife

Dietary exposures were evaluated for terrestrial wildlife feeding in Watson Creek. Table 5-42 presents a comparison of selected toxicity values with estimated exposures in heron, sandpipers, and muskrat. The results of the comparisons are as follows:

- Estimated exposures in heron feeding on fish from Watson Creek are below the toxicity values derived for heron by factors of between 3 and 50.
- Estimated exposures to cadmium, manganese, mercury, and selenium in sandpipers feeding on insects in Watson Creek exceed the toxicity values derived for sandpipers by factors of between 2 and 7.
- Estimated exposure to selenium in muskrat feeding on plants in Watson Creek exceeds the toxicity value by a factor of 30. Exposure to cadmium exceeds the toxicity value by a factor of 10.

These comparisons suggest that wildlife feeding in Watson Creek could be impacted by exposure to heavy metals in their food. Sandpipers and other shore birds feeding on aquatic insects and probably benthic organisms are potentially at greatest risk as many of the inorganic chemicals present in Watson Creek can bioaccumulate significantly in aquatic invertebrates. Piscivorous bird species, such as heron, appear to be at lower risk of impact because most of the metals present accumulate to a lesser degree in fish than in invertebrates. Further, some portion of a piscivore's diet from Watson Creek is probably composed of fish species that are not residents of Watson Creek; nonresident species are likely to accumulate metals from Watson Creek to a lesser degree than resident fish. Herbivorous species such as muskrat appear to be at risk from dietary exposures even though few chemicals in Watson Creek are likely to accumulate in aquatic plants, because the chemicals that could accumulate are relatively toxic at low dietary concentrations.

Heavy metal exposures in wildlife are associated with a variety of toxic effects. For example, dietary exposures to cadmium, selenium, and mercury have been associated with decreased reproductive success in birds, and manganese exposure has been associated with decreased growth. Mercury exposure in mammals can affect reproduction, growth, and development as well as alter a variety of physiological processes. Selenium exposures in mammals can result in abnormal movements, respiratory failure, and death. Such effects could directly affect the health of the wildlife populations in and around Watson Creek, potentially resulting in localized reductions in population size. Because

TABLE 5-41

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN WATSON CREEK SEDIMENT

(Concentrations reported in mg/kg)

Chemical (a)	Toxicity Value (b)	Exposure Concentration (c)	Toxicity Value Exceeded ?
Organic Chemicals:			
PAHs [carcinogenic]	2.0	0.85	No
PAHs [noncarcinogenic]	2.0	0.77	No
Phthalates			
Di-n-butylphthalate (DNBP)	10	0.30	No
Diethylphthalate (DEP)	5.3	0.37	No
Dimethylphthalate (DMP)	22	0.77	No
Inorganic Chemicals:			
Antimony (SB)	150	3.7	No
Copper (CU)	390	33	No
Mercury (HG)	0.8	0.5	No
Zinc (ZN)	760	160	No

(a) USATHAMA chemical codes listed in parentheses. Only chemicals with toxicity values are listed. The following chemicals are not presented due to lack of toxicity criteria: bis(2-ethylhexyl)phthalate, ammonia, beryllium, boron, nitrite, and thallium. Ammonia, boron and nitrite were the only chemicals of concern selected for Gunpowder River sediments.

(b) Reported previously in Table 5-37.

(c) Reported previously in Table 5-27.

TABLE 5-42

COMPARISON OF TOXICITY VALUES WITH ESTIMATED DOSAGES FOR TERRESTRIAL WILDLIFE EXPOSED TO CHEMICALS THAT HAVE ACCUMULATED IN FOOD AT O-FIELD

Receptor Species/ Chemical (a)	Toxicity Value (mg/kg bw)	Estimated Dosage (mg/kg bw)	Toxicity Value Exceeded ?
Heron:			
Cadmium (CD)	0.13	0.05	No
Manganese (MN)	51	1.1	No
Mercury (HG)	0.41	0.07	No
Selenium (SE)	0.61	0.08	No
Sandpiper:			
Cadmium (CD)	0.13	0.88	Yes
Manganese (MN)	51	260	Yes
Mercury (HG)	0.41	0.64	Yes
Selenium (SE)	0.38	6.7	Yes
Zinc (ZN)	7.8	4.1	No
Muskrat:			
Cadmium (CD)	0.015	0.2	Yes
Selenium (SE)	0.06	2.0	Yes

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Tables 5-30, 5-32, and 5-33.

Watson Creek likely supports a small percentage of the total wildlife population of APG, effects in individuals feeding in Watson Creek are unlikely to affect the wildlife population of APG as a whole. Nevertheless, the results of this assessment suggest that the presence of heavy metals in Watson Creek has reduced the value of that area as wildlife habitat. Further, impacts to species in the O-Field area could contribute to cumulative impacts associated with APG as a whole (see Chapter 13).

5.5 UNCERTAINTIES

As in any risk assessment, a large degree of uncertainty is associated with the estimates of human health and ecological risks for the O-Field study area. Consequently, these estimates should not be regarded as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the predicted risks and to placing the predicted risks in proper perspective. The principal sources of uncertainty associated with the APG risk assessments were discussed in general in Chapter 4. Some of the key sources of uncertainty associated with the estimates of risk for the O-Field study area are summarized below.

5.5.1 UNCERTAINTIES RELATED TO SELECTION OF CHEMICALS FOR EVALUATION

Because no site-specific background data were available for surface water and sediment, the site-relatedness of inorganic chemicals in these media was determined by comparing site-related chemical concentrations with background data collected from areas near APG. The degree to which these background data are representative for tidal, estuarine creeks such as Watson Creek or for the Gunpowder River near O-Field is probably limited. As a result, chemicals that may not be site-related were selected for evaluation, even though historical information provides no indication that they are associated with past activities at O-Field (e.g., selenium, cadmium, manganese, antimony). This is particularly critical at O-Field because inorganic chemicals are driving the estimates of impact for terrestrial wildlife and are contributing significantly to estimates of impact in aquatic life. Consequently, including chemicals in the risk assessment that are present at natural levels could result in over-estimates of impact associated with the O-Field site.

Because of sampling limitations, there is uncertainty regarding the true nature and extent of groundwater and soil contamination at O-Field. For example, many chemicals potentially present in O-Field groundwater were not analyzed for (e.g., DIMP, 1,4-dithiane) or were analyzed for only once or twice (e.g., explosives, chemical agents, and some metals). No surface soil samples were collected, and the few subsurface samples that were collected were analyzed for only four inorganic chemicals. Consequently, potential impacts associated with soil exposures could not be evaluated.

There also is uncertainty regarding the true nature and extent of surface water and sediment contamination in Watson Creek and the Gunpowder River. Surface water and sediment analyses did not include analysis for a number of compounds that were detected in groundwater (e.g., thiodiglycol, explosive-related compounds). Because groundwater is known to be discharging to Watson Creek, chemical contamination in addition to that looked for is possible in surface water, possibly resulting in additional impacts in aquatic or terrestrial wildlife not included in this assessment.

With the exception of 1,4-dithiane, no tentatively identified compounds were included in the risk assessment because of the large degree of uncertainty regarding the identity and concentrations of these compounds. However, exclusion of these chemicals from the risk assessment probably has resulted in under-estimates of risk. The magnitude to which risks are underestimated depends on the concentrations of the chemicals as well as their toxicity.

5.5.2 UNCERTAINTIES ASSOCIATED WITH THE MODELS AND ASSUMPTIONS USED TO ESTIMATE EXPOSURES

A large degree of uncertainty in this risk assessment is associated with the estimates of exposure point concentrations. For example, organic chemical concentrations in surface water and sediment pore water concentrations were estimated for several chemicals using a simplistic model of groundwater discharge and surface water dilution within the discharge zone. Generally conservative assumptions were made to estimate surface water concentrations potentially resulting in over-estimates of exposures and risks.

There also is uncertainty associated with the estimates of air concentrations of volatile organic chemicals used to evaluate inhalation exposures in nearby workers. Assumptions regarding source strength and size could result in over- or under-estimates of air emissions, whereas other assumptions regarding dispersion to receptor locations could result in over-estimates of exposure. Total air emissions in this assessment probably have been underestimated given that volatilization from subsurface environments (wastes, soils, and groundwater) could not be evaluated.

The estimates of bioconcentration in aquatic life are also very uncertain. These estimates were based on a simple partitioning model which assumed equilibrium conditions between the aquatic organism and surface water. The approach also assumed that bioaccumulation in species living in Watson Creek was similar to that reported in the literature for other species. The extent to which either of these assumptions is true affects the accuracy of the exposure estimates. Also, total surface water concentrations were used in the model because dissolved concentrations were not available. This results in over-estimates of bioaccumulation, because chemicals that are sorbed onto particles are not available for uptake through the gills.

The assumptions used to estimate intake in both human and terrestrial wildlife receptors also contribute a great deal of uncertainty to the estimates of exposure and impact. Generally conservative assumptions were used when estimating exposures, which may result in over-estimates of actual exposures at O-Field.

5.5.3 UNCERTAINTIES IN THE TOXICITY ASSESSMENT

There is a great deal of uncertainty associated with the estimates of toxicity in terrestrial and aquatic wildlife in this assessment. For example, no aquatic toxicity data were available for several chemicals, and toxicity was estimated using structure-activity relationships. In other cases, aquatic toxicity data were available but only for a few species and typically only for acute exposures. Similarly, few data were available on toxicity in terrestrial wildlife species, and data on domestic species were used to derive the toxicity values used in this assessment. In these instances, toxicity values were estimated by applying uncertainty factors (divisors) to the data. The lack of inhalation toxicity criteria for 1,3-dinitrobenzene and 1,2-dichloroethene could result in underestimates of risk.

5.6 PRINCIPAL DATA NEEDS

Investigations to date have not provided a complete and exhaustive characterization of the type and degree of contamination at O-Field. As a result, additional investigation is needed to assess more definitively existing or potential impacts associated with the O-Field study area. The two principal types of additional data needed to better evaluate impacts at O-Field are (1) data on the nature and extent of contamination and (2) information on aquatic and terrestrial wildlife exposures and/or impacts. Specific data needs within these two categories are summarized below.

Data on the Nature and Extent of Contamination

- Background surface water and sediment samples are needed to permit a more accurate assessment of the site-relatedness of inorganic chemicals in Watson Creek and the Gunpowder River. Background samples for Watson Creek should be collected from a similar tidal creek system, preferably one that has been partially dammed like Watson Creek. Swaderick Creek, located on the Gunpowder Neck north of O-Field may be a potential background location for Watson Creek. Background samples for the Gunpowder River could be collected upstream of O-Field. A sufficient number of samples should be collected to permit statistical evaluation.

- Additional surface water samples should be collected from Watson Creek and the Gunpowder River. Ideally, the samples should be collected at varying times to characterize daily changes in surface water contamination that may result from variations in groundwater discharge, tidal effects, dilution, and volatilization. This is particularly important for samples collected from Watson Creek in the groundwater discharge zone. Samples of sediment pore water in the groundwater discharge zone would provide a better indication of potential exposure concentrations for benthic species. Total and dissolved concentrations should be measured.

- Surface soil samples should be collected so impacts to terrestrial wildlife can be evaluated, along with those for any future users at O-Field.

- Samples from all media should be sampled for the range of military-unique and other compounds potentially present at O-Field.

Data Related to Wildlife Exposures and/or Impacts

- Fish and invertebrates (both benthic and water-column species) should be collected for whole-body residue analysis. Efforts should be made to collect resident fish species and year-round and seasonal populations of invertebrates (i.e., aquatic insect larvae). Bottom-feeding and predatory species should be included in the fish samples. Analytes should include at a minimum all priority pollutant metals, and ideally encompass a range of organic chemicals potentially present at O-Field that could accumulate in aquatic organisms. Suitable background samples are needed for evaluation of these results.

- Aquatic macrophytes should be collected for residue analysis. Again, analytes should include all chemicals potentially present that could accumulate in plants. Suitable background samples are needed for evaluation of these results.

- Benthic macroinvertebrate species surveys are needed to provide some indication on the nature of impacts (if any) to sediment-dwelling species in Watson Creek. Studies should include benthic species samples from a suitable background location (possibly Swaderick Creek) and from within and outside the groundwater discharge zone in Watson Creek. Possible evaluation endpoints include species number and species diversity.

- Sediment toxicity studies are needed to assess impacts associated with chemicals sorbed onto sediments as well as chemicals discharged from groundwater through sediments and present in sediment pore water. Suitable laboratory and field controls are needed.

- Aquatic toxicity tests are needed to assess the toxicity of water from Watson Creek. Tests should include acute toxicity tests and chronic or early life-stage tests with invertebrates, algae, and fish. Tests should be conducted with water collected within the groundwater discharge zone in Watson Creek and from other areas of Watson Creek and the Gunpowder River.

5.7 SUMMARY AND CONCLUSIONS

This baseline risk assessment addressed potential impacts on human health and the environment associated with the O-Field study area in the absence of remedial actions. The hydrogeologic field investigation conducted by USGS (1988, 1989) was the primary source of sampling data considered in this assessment. Sampling data were available for subsurface soil, groundwater, surface water, and sediment. Chemical analyses were limited primarily to volatile, semivolatile, and inorganic chemical analyses, although selected groundwater samples were analyzed for agent- and explosive-related compounds, herbicides, and radionuclides. Based on these sampling results, volatile organic chemicals and inorganic chemicals (principally metals) are the primary chemicals of concern in groundwater and surface water, whereas PAHs, phthalates, and metals are the principal chemicals of concern in sediment. Too few data are available to identify the primary chemicals of concern in subsurface soils. Agent degradation products and explosive-related compounds are also of concern in groundwater (the only medium sampled for these compounds).

5.7.1 HUMAN HEALTH RISK ASSESSMENT SUMMARY

The primary pathways by which human populations could be exposed to chemicals of potential concern under current land-use conditions are (1) chronic exposures via inhalation of chemicals that have volatilized from Watson Creek, and (2) acute exposures via inhalation and dermal exposures to chemical agents released from O-Field as a result of a fire, explosion, or subsurface spill (discussed in the "Design Report for the Old O-Field Source Area - Final Document" (February 1995) and for a similar scenario in "Installation Restoration Program - Cluster I: Former Nike Site - Aberdeen Proving Ground Remedial Investigation/Feasibility Study, Volume I: Remedial Investigation Report, Appendix O.". No other potential pathways are likely to result in significant exposure under current land-use conditions. The only human exposure pathways potentially complete under future land-use conditions are (1) direct contact with chemicals in surface soils by persons using O-Field, (2) inhalation of chemicals that have volatilized from surface water by persons using O-Field, and (3) dermal contact and incidental ingestion of chemicals in surface water by persons swimming in the Gunpowder River.

The chronic exposure pathways under current land-use conditions were evaluated quantitatively, and those under future land-use conditions were evaluated qualitatively. Chronic inhalation exposures under current land-use conditions were evaluated for workers at H-Field, M-Field, and New O-Field. Two exposure estimates were generated for these receptors based on high and low estimates of volatile emissions from Watson Creek surface water. Soil and inhalation exposures under future land-use conditions were evaluated for workers at Old O-Field. Surface water exposures were evaluated for recreational users of the Gunpowder River.

The estimated human health risks associated with these pathways are as follows:

Current Land Use

- For H-Field receptors, the upper-bound excess lifetime cancer risk ranges from $8x10^{-8}$ to $3x10^{-7}$. For M-Field receptors, the upper-bound excess lifetime cancer risk ranges from $7x10^{-8}$ to $2x10^{-7}$. For New O-Field receptors, the upper-bound excess lifetime cancer risk ranges from $4x10^{-8}$ to $1x10^{-7}$. The risk estimates are below the $1x10^{-6}$ risk level often used by regulatory agencies to determine the need for corrective action at a site. For all receptors, the Hazard Index is less than one, indicating that inhalation exposures evaluated are unlikely to be associated with noncarcinogenic health effects.

INFORMATION IN THIS SECTION REGARDING ACUTE EXPOSURES TO CHEMICAL AGENTS RESULTING FROM EXPLOSIONS OR SPILLS HAS BEEN REMOVED BECAUSE OF INACCURACIES ASSOCIATED WITH THE ORIGINAL DATA. RECENT INFORMATION REGARDING ACUTE EXPOSURES FOR SPECIFIC CHEMICAL AGENTS AT O-FIELD CAN BE FOUND IN THE "DESIGN REPORT FOR THE OLD O-FIELD SOURCE AREA - FINAL DOCUMENT" (FEBRUARY 1995), AND FOR A SIMILAR SCENARIO IN "INSTALLATION RESTORATION PROGRAM - CLUSTER I: FORMER NIKE SITE - ABERDEEN PROVING GROUND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, VOLUME I: REMEDIAL INVESTIGATION REPORT, APPENDIX O."

Future Land Use

- Direct contact exposures with chemicals in soils at Old O-Field would result in significant health risks in exposed individuals if use restrictions were lifted in the future. This is because the chemicals potentially present in surface soils at Old O-Field can cause relatively severe toxic effects, ranging from acute lethality (e.g., mustard, VX) to cancer (e.g., PAHs, phthalates). Furthermore, these chemicals are potentially present at high concentrations in surface soil, particularly in localized areas where spills or disposal occurred.

- Potential risks to workers at Old O-Field exposed via inhalation to volatile chemicals are likely to be less than those associated with direct contact exposures. The risks for this pathway probably would be increased but within an order-of-magnitude of those estimated for workers at New O-Field, given that workers at Old O-Field would be closer to the emission source and could be exposed more frequently than current workers at New O-Field. Thus, excess lifetime cancer risks in the range of 10^{-7} to 10^{-6} would be possible. Hazard Indices would remain below one. However, potentially significant risks are possible.

- Persons swimming in the Gunpowder River near O-Field are not likely to experience significant health risks due to the low concentrations of the chemicals relative to toxic concentrations. Even under the totally implausible assumption of a person swimming in the Gunpowder River near O-Field every day for 70 years and being continuously exposed to the maximum detected concentrations in the river, the excess lifetime cancer risk would be in the range of $4x10^{-6}$.

5.7.2 ECOLOGICAL ASSESSMENT SUMMARY

Potential ecological impacts were evaluated for aquatic and terrestrial wildlife at O-Field. Aquatic life exposures were evaluated for chemicals in surface water and sediment in Watson Creek and the Gunpowder River. In addition, exposures were evaluated for benthic species living in the groundwater discharge zone in Watson Creek. Terrestrial wildlife exposures were evaluated for heron (a piscivore).

sandpipers (an aquatic insectivore), and muskrat (aquatic herbivore) feeding in Watson Creek and exposed to chemicals that have accumulated in food.

The results of the assessment are as follows:

Aquatic Life Impacts

- Surface Water Exposures. Aquatic life in Watson Creek and the Gunpowder River are probably being impacted by surface water chemical contaminants associated with O-Field. Impacts in Watson Creek are likely more severe than those in the Gunpowder River, given the greater number of chemicals present at higher concentrations in the creek. Also, the more closed nature of Watson Creek relative to the Gunpowder River probably makes it more susceptible to impacts than the river. Impacts associated with organic contaminants in Watson Creek are probably localized to the area of groundwater discharge, which likely has the highest concentrations of volatile organic chemicals being released to surface water. Predicted impacts on benthic species living within this area were greater than those predicted for species living within the water column. Impacts associated with inorganic contaminants are probably more widespread, given the relatively even distribution of these chemicals throughout the creek.

- Sediment Exposures. Chemical concentrations in Watson Creek and Gunpowder River sediments are below those predicted to be harmful to aquatic life, suggesting that aquatic life impacts from exposure to chemicals in sediment are not likely. However, the sediment toxicity values were derived from a very limited toxicity database and therefore may not necessarily be protective of aquatic life.

Terrestrial Wildlife

- Wildlife feeding in Watson Creek could be impacted by exposure to heavy metals in their food. Sandpipers and other shore birds feeding on aquatic insects and probably benthic organisms are potentially at greatest risk of impact as many of the inorganic chemicals present in Watson Creek can bioaccumulate significantly in aquatic invertebrates. Piscivorous bird species, such as heron, do not appear to be at risk because most of the metals present accumulate to a lesser degree in fish than in invertebrates. Further, heron are much less susceptible than sandpipers to impact from O-Field, because they feed over a much larger area than do sandpipers or other small shore-birds. Herbivorous species such as muskrat appear to be at risk from dietary exposures even though few chemicals in Watson Creek are likely to accumulate in aquatic plants because the chemicals that could accumulate could be toxic at relatively low dietary concentrations.

5.7.3 CONCLUSIONS OF THE RISK ASSESSMENT

Past activities at O-Field have resulted in significant contamination of groundwater, surface water, and sediment in the area. Few data are available on chemical concentrations in the soil, but soil contamination is probably significant. Under current land-use conditions, ecological populations are the principal receptors of concern. Few human health exposure pathways exist under current land-use conditions. Only the release of chemical agent as a result of an explosion or spill at O-Field is likely to be associated with increased health risks (discussed in the "Design Report for the Old O-Field Source Area - Final Document" (February 1995) and for a similar scenario in "Installation Restoration Program - Cluster I: Former Nike Site - Aberdeen Proving Ground Remedial Investigation/Feasibility Study, Volume I: Remedial Investigation Report, Appendix O." Additional human health risks would result if use restrictions at O-Field were lifted in the future.

It is possible that the aquatic life in Watson Creek and the Gunpowder River and terrestrial wildlife feeding in Watson Creek are being adversely affected by chemical contamination associated with O-Field.

Acute and chronic toxicity in O-Field surface waters probably has affected the composition and structure of the aquatic communities in Watson Creek and possibly the Gunpowder River near O-Field. Localized reductions in species diversity and number for resident aquatic life (particularly in Watson Creek) are possible, as are impacts in nonresident species that use the area as a nursery area (e.g., blueback herring, bay anchovy, menhaden). Because the O-Field area supports only a small percentage of the entire aquatic community of APG, impacts there are unlikely to have a significant effect on the aquatic populations at APG or in the northern Chesapeake Bay. They could, however, result in localized reductions in population size and contribute to cumulative impacts associated with APG as a whole.

Wildlife feeding in Watson Creek appear to be at risk from exposure to heavy metals in the diet. Dietary exposures to heavy metals can induce a variety of toxic effects in wildlife, including decreased reproductive success, decreased growth, and abnormal behavior. Such effects could directly affect the health of the wildlife populations in and around Watson Creek. Such localized effects are unlikely to affect the wildlife population of APG as a whole. Nevertheless, the presence of heavy metals in Watson Creek appears to have reduced the value of that area as wildlife habitat. Further, impacts in species in the O-Field area could contribute to cumulative impacts associated with APG as a whole.

These estimates of risk, however, should not be regarded as absolute. There is a great deal of uncertainty associated with all risk estimates for the O-Field study area, because of limitations associated with the available sampling data and limitations inherent to the risk assessment process. Additional investigation is needed to assess more definitively existing or potential impacts associated with the O-Field study area.

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6.0 J-FIELD RISK ASSESSMENT

This chapter evaluates potential impacts on human health and the environment associated with the J-Field study area in the absence of remedial (corrective) actions. Sampling data collected by USGS in 1988 and 1990 are used to evaluate potential risks in this assessment. This study was selected for use in risk assessment because it was the most recent study conducted at J-Field. Data from other studies conducted at J-Field are briefly discussed where applicable to support evaluations of potential exposures or risks. All data summarized in this assessment were obtained directly from the USATHAMA database (IRDMS).

The USGS investigation and other investigations conducted to date have not completely characterized the nature and extent of contamination at J-Field. Furthermore, USGS data contained in IRDMS are not yet complete, and represent only a subset of the analytical data gathered as part of the USGS study. Therefore, this risk assessment should be considered largely preliminary and is intended as an initial step in the overall risk assessment process for J-Field.

This assessment follows the general methodology outlined in Chapter 4 of this report, which should be consulted for the rationale and further details of the methods used in this assessment. This assessment is organized into eight primary sections:

- Section 6.1 Background Information
- Section 6.2 Selection of Chemicals of Potential Concern
- Section 6.3 Human Health Risk Assessment
- Section 6.4 Ecological Assessment
- Section 6.5 Uncertainties
- Section 6.6 Principal Data Needs
- Section 6.7 Summary and Conclusions
- Section 6.8 References

6.1 BACKGROUND INFORMATION[1]

J-Field is a hazardous waste and ordnance disposal site, which was used during the late 1940s for disposal of solvents, chemical warfare agents, and related wastes by open-pit burning. Since the late 1940s, J-Field has been used for open-pit burning of solvents, chemical warfare agents, and related wastes, and to a lesser extent, for testing of munitions and chemical agents. The limited testing activities that occurred consisted mostly of high explosive testing and some chemical agent testing on a small scale.

J-Field is located on the southern end of Gunpowder Neck immediately south of I-Field. It is bounded on the south and east by the Chesapeake Bay and on the west by the Gunpowder River (see Figure 6-1). The J-Field area is approximately 460 acres in size.

Prior to 1970, J-Field was used for the disposal of many types of chemical agents and chemical-filled munitions. These include many tons of 250-kg sarin-filled bombs, white phosphorus-filled munitions,

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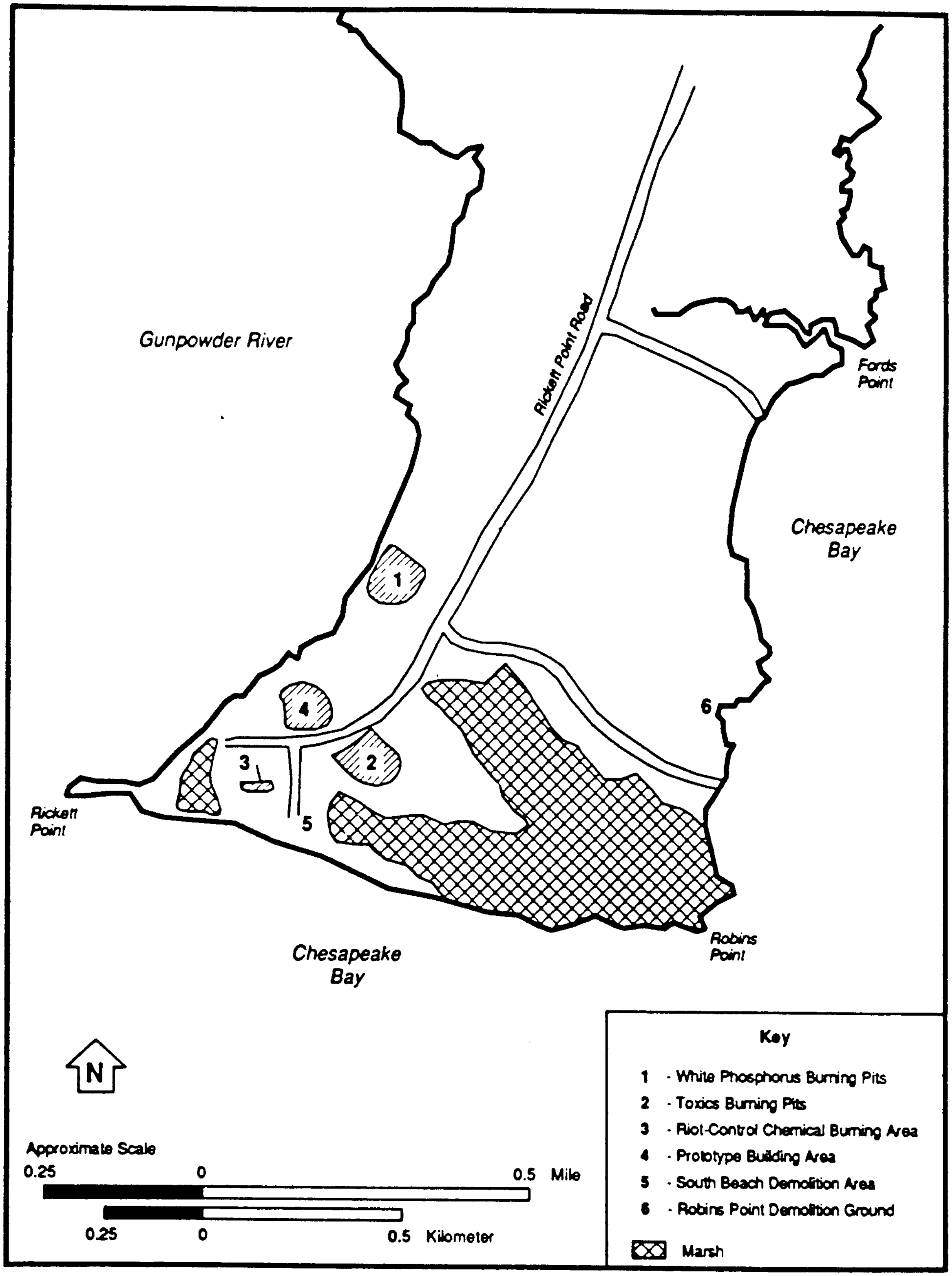
[1] The historical information summarized in this section was derived primarily from USGS (1990).

Figure 6-1
J-Field Study Area



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adamsite, napalm, and mustard-filled ton containers. There also may be explosive, incendiary, and chemical-filled munitions at J-Field given its proximity to firing range impact areas at I-Field and its prior use as a test site chemical agent rockets during the Korean and Vietnam Wars. A list of the principal compounds believed to have been used or disposed of at J-Field is given in Table 6-1.

There are six sites at which disposal or management of potentially hazardous waste occurred. These sites are (1) the toxic burning pits; (2) the white phosphorus burning pits; (3) the riot control chemical burning area; (4) the Robins Point demolition ground; (5) the South Beach demolition area; and (6) the Prototype Building area. These areas are shown in Figure 6-1 and discussed below.

Toxic Burning Pits. The toxic burning pits at J-Field were used from the late 1940s until recent times for the disposal of chemical-filled munitions, liquid smoke materials (probably FM or FS), drummed chemical wastes, and materials potentially contaminated with chemical agents. The chemical agents believed to have been disposed of in these pits include nerve agents, incapacitating agents, and mustard; little or no arsenicals are believed to have been disposed here. The pits were used extensively from the late 1940s through the 1960s but have had only limited use since 1970. Recent use has been only for emergency disposal operations. Two pits currently exist uncovered; the remaining pits have been covered.

Burial was never used as a disposal method in this area; all wastes were burned. Items to be burned were covered with 3-4 feet of dunnage and fuel oil and then ignited. The pits were maintained by pushing residue out the end of the pits eastward towards the marsh. This action has moved the edge of the marsh 100 feet to the east.

Monitoring at the pits after burning indicated that little or no chemical agent remained. However, drummed chemical waste consisting of nonflammable liquid waste, such as trichloroethene and other chlorinated solvents, likely had a much lower destruction efficiency and some free solvent likely remained after burning.

White Phosphorus Pits. The white phosphorus pits were used for the disposal of white phosphorous, white phosphorus-filled munitions, and materials contaminated with white phosphorus. Disposal was by detonation and burning. The site has been used since the late 1940s or early 1950s and is still used for emergency disposal of white phosphorus. Two existing pits were constructed between 1951 and 1957. The disposed material was burned in the first pit and then reburned in the second pit. In 1986, the pits were modified by the construction of a drainage ditch designed to carry water from the pits northward, away from the Gunpowder River, to a bermed depression constructed to hold the water.

The primary wastes disposed of at this site were white phosphorus, red phosphorus, and plasticized white phosphorus. Other wastes that may have contained white phosphorus were disposed of here to avoid white phosphorus contamination in other areas. Some historical accounts suggest that there also may have been some disposal of riot control agents, such as chloroacetophenone in these pits, although chemical analyses to date have not indicated the presence of this or related compounds.

Riot Control Chemical Burning Area. The Riot Control Chemical Burning Area was probably used as early as the late 1940s. Aerial photographs confirm its existence by 1951. Chemicals, chemical-filled munitions, and materials contaminated with chemicals were disposed of here by burning. A burning trench was constructed between 1957 and 1960 and lengthened in the 1960s to the Gunpowder River shoreline for drainage from the pit. Before the trench was built, the site was probably an open burning area.

TABLE 6-1

PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT J-FIELD (a)

Group	Chemical Compound (Acronym) (b)
Lethal Chemical Agents	Tabun (GA) [in bombs] Sarin (GB) Various G-agents Mustard (H) [in ton containers] Mustard [in various forms] VX Blood Agent [possibly CK]
Incapacitating Agents	Adamsite (DM) Chloroacetophenone (CN) o-Chlorobenzylidene Malononitrile (CS)
Decontaminating Agents	Calcium Hypochlorite (HTH) Sodium Hydroxide (NaOH)
Smoke/Incendiary Materials	Napalm Liquid Smoke materials (FM and/or FS) Red Phosphorus White Phosphorus (WP) [WP-filled munitions] Plasticized White Phosphorus (PWP)
Munitions Compounds	High Explosives (HE) 2,4,6-Trinitrophenyl Methyl Nitramine Comp. B [40% TNT and 60% HMX]
Solvents	Chlorinated Solvents
Oils/Fuels	Fuel oil Oil resin Fog oil
Miscellaneous Compounds	Radioactive waste [possible test burning] Diethyl Ether Picric Acid Particulate filters Peroxides and Ethers Uranyl Acetate Hydrazine Sulfate Chlorine Trifluoride Sulfur Trioxide - Chlorosulfamic Acid Ammonium Hydroxide Atropine PCBs [Aroclor 1248]

(a) Information obtained primarily from USGS (1990).
(b) See Glossary of Acronyms and Abbreviations for complete chemical name if not given in this table.

From 1960 to the early 1970s, riot control agents and materials containing or contaminated with riot control agents were burned here. The primary chemical disposed of was the tear agent CS. It is also likely that chloroacetophenone was disposed here. It is not known what types of wastes were discarded here before 1960, but they probably were similar to those disposed of after that time, but on a smaller scale. No lethal chemical agents or white phosphorus are believed to have been disposed here, because other sites existed at J-Field for their disposal.

Robins Point Demolition Ground. The Robins Point Demolition Ground is used for the destruction of explosive materials. It was first used in the late 1970s. Originally, the site was a small clearing with demolition occurring along the edge of the marsh at the east edge of the clearing. Modifications were made in 1985, when the clearing was enlarged and a berm was built west of the original site of demolition work. High explosive items have been detonated in this area. An item filled with a blood agent, most likely cyanogen chloride, was once destroyed here.

South Beach Demolition Area. The South Beach Demolition Area was a demolition site for high explosive munitions during the 1960s and early 1970s and perhaps the 1950s. Detonations occurred at ground surface or several feet deep.

Prototype Building Area. The Prototype Building Area was built during WWII to test the effectiveness of bombing against a structure. The building itself is an open-sided three-level reinforced concrete structure. Since WWII, the building has occasionally been used as a temporary storage facility. The areas west and north of the building also were used as open storage areas. It is likely that solid wastes of certain types were stored in the structure or in a nearby open area. Contamination, therefore, would be due to leakage or spillage.

6.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

In this section, environmental monitoring data collected by USGS in 1988 and 1990 at J-Field and obtained from IRDMS are briefly summarized, and chemicals of potential concern are identified. Sampling data are available only for groundwater and surface water. Soil and sediment sampling were not conducted as part of the USGS study. Groundwater and surface water sampling data are discussed separately below.

6.2.1 GROUNDWATER

During May and June 1990, USGS collected groundwater samples from both preexisting and newly installed monitoring wells. Samples were collected from 7 wells previously installed by USATHAMA, 9 wells installed by Princeton Aqua Science in 1983, and 12 wells recently installed by USGS. The wells installed by USGS were screened to allow sample collection at three depths. Data from a total of 53 samples (including 2 background samples) were selected for use in this risk assessment.

Groundwater samples were collected from varying depths to characterize potential contamination in the water-bearing zones underlying J-Field. Samples were collected from immediately above a low permeability soil layer, from within this layer, and immediately below this layer. However, because a hydraulic connection exists between the zones underlying J-Field (i.e., through the low permeability layer), sampling data from all depths were grouped together. Samples from different depths at a given location were treated as individual samples (i.e., they are not averaged together as were duplicates).

Ten groundwater wells were located near the white phosphorus pits, 11 near the toxic pits, 3 near the prototype building, 2 near the riot control agent pit, 1 near the South Beach demolition area, and 1 near Robins Point. Groundwater data from all the source areas except Robins Point were analyzed together, because no significant differences in contaminant type and distribution were apparent among the source areas. The data from Robins Point were analyzed separately because of its geographic distance from the other source areas.

Groundwater samples were analyzed for volatile and semivolatile organic chemicals, major ions (e.g., calcium, chloride, magnesium), other inorganic constituents, pesticides, PCBs, explosives and related compounds, and organosulfur compounds. Explosive compounds that were analyzed for are:

- Trinitrotoluene
- 2,4-Dinitrotoluene
- 2,6-Dinitrotoluene
- HMX
- RDX
- 1,3,5-Trinitrobenzene
- 1,3-Dinitrobenzene
- Nitroglycerin
- Nitrocellulose
- Pentaerythritol tetranitrate (PETN)
- Tetrazene
- 2,4,6-Trinitrobenzaldehyde
- Tetryl
- Nitrobenzene.

Organosulfur compounds analyzed for are:

- 1,4-Oxathiane
- 1,4-Dithiane
- Benzothiazole
- Thiodiglycol
- p-Chlorophenylmethyl sulfone
- p-Chlorophenylmethyl sulfide
- p-Chlorophenylmethyl sulfoxide

Radiological parameters also were analyzed in selected groundwater samples.

Currently, IRDMS contains only a subset of the groundwater analytical results. For example, data for most explosive compounds are available for only 11 or 12 samples, and no data are available for three of these compounds (nitrocellulose, tetrazene, and 2,4,6-trinitrobenzaldehyde). Of the organosulfur compounds, no sample data are available for thiodiglycol, and data from only eight samples are available for benzothiazole. The sample data for the other organic chemicals and some of the inorganic chemicals are not complete. For example, data for volatile organic chemicals are available for only 22 or 23 samples, and data regarding radiochemistry analyses are not available. Therefore, this risk assessment is based on an incomplete database. For these reasons, any conclusions regarding groundwater should be considered very preliminary.

Two samples were identified as potential background samples based on available hydrological information: J-007, a well installed by USATHAMA approximately midway between the white phosphorus pits and Robins Point, and JF-002, a well installed by USGS located approximately 2,000 feet northeast of the white phosphorus pits. J-007 is screened in the same aquifer units as the other wells located near the source areas, and would therefore be an appropriate background well for these other areas. The sample from J-007 reportedly was analyzed for all the groundwater target compounds listed previously, but data are currently available only for three inorganic chemicals. Therefore, the usefulness of this well as background is limited at the present time. JF-002 is located in a Cretaceous aquifer. Mineralogical properties in Cretaceous wells are likely to differ from those in the shallower wells, and therefore this well may not be an appropriate source of background concentrations for the other J-Field wells.[2] However, if this well is not used for J-Field background, the only alternative background levels are national background data, which are probably less likely than JF-002 data to be representative of on-site groundwater conditions. Therefore, the Cretaceous aquifer data were used as background concentrations for this assessment. JF-002 was not analyzed for lead and nitrate/nitrite, so national background data as reported in Walton (1985) were used for these two chemicals.

Because only one background location was available, a statistical comparison of chemical concentrations in on-site wells to local background chemical concentrations could not be conducted. Instead, concentrations detected at downgradient sampling locations were compared to background concentrations. Chemical concentrations were considered to be site related if the maximum downgradient concentration was more than twice the on-site background concentration or if it was within the range of national background values (see Chapter 4 for rationale).

Table 6-2 presents the frequency of detection and range of concentrations for the chemicals detected in all downgradient wells (except Robins Point wells) along with information on chemical concentrations in the upgradient well near J-Field (JF-002). (No chemicals were detected in a limited analysis of the Robins Point sample [arsenic, lead, selenium only].) A number of volatile organic chemicals were detected in J-Field groundwater at maximum concentrations from 4.3-150 µg/L. Only one of these chemicals (trichloroethene) was detected in the upgradient well, which suggests that their presence is site-related. The presence of trichloroethene in the upgradient well sample could be the result of cross contamination or may reflect an upgradient source of this chemical.

The volatile organic chemicals in groundwater could be a result of direct disposal of solvents (e.g., trichloroethene) at J-Field and/or a result of degradation of parent compounds. In groundwater, under anaerobic conditions, chlorinated alkanes and alkenes such as those detected in J-Field groundwater undergo reductive dechlorination reactions in which chlorine is sequentially removed from chemicals (Bouwer et al. 1981, Kobayashi and Rittman 1982). For example, tetrachloroethene is reduced to trichloroethene, which is further reduced, yielding dichloroethene and ultimately vinyl chloride. An examination of the chemicals detected in groundwater at J-Field suggests that some dechlorination reactions probably are occurring. Tetrachloroethene was measured together with its degradation products trichloroethene, dichloroethenes, and vinyl chloride. Similarly, 1,1,2,2-tetrachloroethene and its degradation product 1,1,2-trichloroethane were detected. As mentioned above, however, some of these compounds are likely present as a result of solvent disposal at J-Field.

The relatively low levels of volatile organic chemicals (maximum of 150 µg/L) is surprising given that large quantities of chlorinated solvents are believed to have been disposed at J-Field in the toxic burning pit area. Because solvents are not very flammable, it is likely that some quantity of pure solvent leached directly to subsurface soils during disposal. Given the nature of past waste disposal, it is conceivable that some pure solvent is present in the subsurface environment and could be acting as a continuing source to groundwater.

Three explosive compounds (nitrobenzene, PETN, and RDX) and three organosulfur chemicals (1,4-dithiane, 1,4-oxathiane, and p-chlorophenylmethyl sulfone) were the only other organic chemicals detected in J-Field groundwater. Of the explosive compounds, only RDX was detected in more than one sample (3/12 samples). The organosulfur compounds occurred with very low frequency; 1,4-dithiane in 2/49 samples, and both 1,4-oxathiane and p-chlorophenylmethyl sulfone in only 1/49

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[2] Brian Hughes, USGS, personal communication. November 1990.

TABLE 6-2

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT J-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	
		Downgradient (d)	Upgradient (e)
Organic Chemicals:			
* Acetone (ACET)	6 / 23	86.4 - 146	ND
* Benzene (C6H6)	3 / 22	0.9 - 116	ND
* Chlorobenzene (CLC6H5)	1 / 22	2.5	ND
* Chloroform (CHCL3)	7 / 23	1.9 - 24	ND
* 1,1-Dichloroethene (11DCE)	4 / 23	3.8 - 34.6	ND
* 1,2-Dichloroethene [Total] (12DCE)	7 / 22	7.3 - 150	ND
* 2,4-Dimethylphenol (24DMPN)	1 / 41	4.3	ND
* 1,4-Dithiane (DITH)	2 / 49	2.1 - 8.2	ND
* Nitrobenzene (NB)	1 / 11	0.9	NA
* 1,4-Oxathiane (OXAT)	1 / 49	8.2	ND
* p-Chlorophenylmethyl Sulfone (CPMSO2)	1 / 49	20.5	ND
* Pentaerythritol Tetranitrate (PETN)	1 / 11	15.9	NA
* Phenol (PHENOL)	2 / 42	18.5 - 23.7	ND
* RDX	3 / 12	0.5 - 1.2	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	3 / 23	7.5 - 150	ND
* Tetrachloroethene (TCLEE)	3 / 23	17.6 - 53.7	ND
* 1,1,1-Trichloroethane (111TCE)	1 / 22	3.0	ND
* 1,1,2-Trichloroethane (112TCE)	2 / 22	10.3 - 100	ND
* Trichloroethene (TRCLE)	9 / 22	1.8 - 150	6.7
* Vinyl Chloride (C2H3CL)	1 / 22	132	ND
Inorganic Chemicals:			
* Arsenic (AS)	14 / 51	2.7 - 60.0	1.9
Bromide (BR)	4 / 36	981 - 2,840	669
Chloride (CL)	37 / 37	1,030 - 390,000	76,000
* Cyanide (CYN)	6 / 27	11.1 - 88.0	ND
* Fluoride (F)	36 / 37	178 - 1,450	352
* Lead (PB)	1 / 14	124	NA (100) (g)
Nitrite/Nitrate (NIT) (f)	17 / 20	10.2 - 1,500	NA (10,000) (g)
* Selenium (SE)	4 / 51	3.0 - 6.2	ND
* Sulfate (SO4)	37 / 37	1,450 - 275,000	407

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Inorganic chemical concentrations are dissolved, except for cyanide, which is reported as total concentration.
(d) Samples: W1-W9; J01, J03, J04, J06, J08, J10; and JF01-JF012 at three different depths.
(e) Sample: JF002.
(f) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.
(g) Value reported represents the upper end of typical background concentrations reported nationwide (Walton 1985).

* = Selected as a chemical of potential concern. See text.
ND = Not detected.
NA = Not analyzed in this sample.

samples. No pesticides or PCBs were detected in groundwater at detection limits of less than 1 µg/L. Despite the low frequency of detection for several of these chemicals, all organic chemicals detected in J-Field groundwater were selected as chemicals of potential concern, given the incomplete nature of the existing data.

A variety of inorganic chemicals were detected in the shallow groundwater at J-Field. All inorganic chemicals except bromide and chloride (both of low toxicity) were detected in J-Field groundwater at concentrations elevated above background concentrations and were selected as chemicals of potential concern.

Cyanide was measured in 6/27 groundwater samples. Although the maximum concentration was not high (88 µg/L), cyanide is not typically found at this level unless cyanide-containing wastes are present or were disposed of in the past. The actual form of cyanide present and migrating in groundwater is unknown, but this chemical may be present in groundwater as a result of combustion or hydrolysis of tabun, which would result in some hydrogen cyanide formation. Hydrogen cyanide is very soluble in water and would not adsorb appreciably to soil organic carbon. It is therefore extremely mobile in the subsurface. In groundwater or soil containing available iron, hydrogen cyanide would tend to form ferricyanide and ferrocyanide anions, which are also very mobile in the subsurface environment.

6.2.2 SURFACE WATER

Twenty-one surface water samples were collected in September 1988 from surface water along the J-Field shoreline. Nine sites were located in the Gunpowder River along the shoreline, nine sites were located along the southern shore of J-Field in the Chesapeake Bay, two sites were located east of the shoreline at Robins Point, and one site was located along a shallow pond in the white phosphorus pits. Surface water samples were analyzed for volatile organic chemicals, selected inorganic chemicals, and major ions and other water quality parameters. However, the sampling data contained in IRDMS do not reflect a complete set of these analyses for all samples.

Table 6-3 summarizes the J-Field surface water sampling data. All data collected from the J-Field shoreline are summarized together, and data from the white phosphorus pit pond are summarized separately.

No site-specific background surface water samples were collected as part of the USGS study. Therefore, J-Field surface water data are compared to background data from other surface waters located near APG (presented in Table 6-3) to identify inorganic chemicals that may be site related (see Chapter 4 for data sources and comparison methodology).

6.2.2.1 J-Field Shoreline

As shown in Table 6-3, the only organic constituent detected in surface water samples is toluene, which was detected only once at the relatively low concentration of 3.1 µg/L. Toluene is conservatively included as a chemical of potential concern although it was detected only once in 20 samples. However, it is possible that toluene is not site-related, given that it was not detected in any groundwater sample. Toluene is a common laboratory contaminant and could be present as an analytical artifact. No blank data were available by which to evaluate the site-relatedness of toluene.

TABLE 6-3

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT J-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentrations (d)
J-FIELD SHORELINE (e)			
Organic Chemicals:			
* Toluene (MEC6H5)	1 /20	3.1	NA
Inorganic Chemicals:			
* Arsenic (AS)	3 / 20	3.6 - 5.0	<1
Barium (BA)	20 / 20	37.9 - 60.5	74
Calcium (CA)	20 / 20	90,000 - 130,000	4,400 - 14,000
Chloride (CL)	3 / 3	4,100,000 - 4,700,000	12,000 - 46,000 (f)
Chromium (CR)	10 / 20	3.7 - 27.0	42
* Lead (PB)	11 / 20	1.5 - 25.0	5
Magnesium (MG)	20 / 20	290,000 - 410,000	2,000 - 7,100
* Mercury (HG)	15 / 20	0.1 - 0.5	0.1
* Nickel (NI)	4 / 20	17.5 - 33.7	6
Nitrite/Nitrate (NIT) (g)	3 / 3	360 - 400	100 - 5,300
Phosphate (PO4)	1 / 3	121	NA
Sodium (NA)	20 / 20	2,350,000 - 6,700,000	6,700 - 21,000
* Sulfate (SO4)	3 / 3	540,000 - 660,000	7,000 - 21,000 (f)
Zinc (ZN)	20 / 20	15.9 - 133	75
WHITE PHOSPHORUS PIT (h)			
Inorganic Chemicals:			
Barium (BA)	1 / 1	5.6	74
Magnesium (MG)	1 / 1	4,030	2,000 - 7,100
Mercury (HG)	1 / 1	0.2	0.1
Sodium (NA)	1 / 1	5,400	6,700 - 21,000
Zinc (ZN)	1 / 1	13.3	75

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Total concentrations reported.
(d) Background concentrations from surface water near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(e) Samples: JFSW-1 - JFSW-20.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.
(h) Sample: JFSW-29.

* = Selected chemical of potential concern. See text.
NA = Not available.

It is interesting to note that none of the volatile organic chemicals present in groundwater were detected in surface water, which could be due to a number of reasons.

- As is the case at other APG areas (e.g., O-Field), groundwater flow at J-Field may be tidally influenced, resulting in pulsed releases of groundwater into surface water. Therefore, surface water samples could have been collected at a time of day after groundwater discharge had occurred and after discharged chemicals had volatilized. Monitoring concentrations over a number of tidal cycles is necessary to characterize the potential tidal influence on groundwater discharge.

- Preliminary information provided by USGS[3] indicates that in addition to possible tidal fluctuations, seasonal fluctuations in the direction of groundwater flow may occur. Groundwater could be discharging to the Gunpowder River or Chesapeake Bay during some seasons and to the wetlands at J-Field during others. Surface water sampling was conducted only in the fall, when groundwater may have been discharging to the wetlands and not the Gunpowder River or Chesapeake Bay.

- It also is possible that groundwater was discharging to the Chesapeake Bay or Gunpowder River, but not at the point where surface water samples were collected.

- Finally, it is possible that groundwater discharge to the Chesapeake Bay may not be significant, and the majority of contamination could be released to the wetlands.

Given the number of factors that may influence the release of groundwater contaminants to surface water, it is apparent that additional sampling, conducted at different times of year and under various tidal conditions, is necessary to characterize the true nature of contamination in J-Field surface water.

Of the inorganic chemicals for which analytical data are available, arsenic, lead, mercury, nickel, and sulfate were detected in samples from the J-Field shoreline at concentrations estimated to be above local background concentrations. These five inorganic chemicals were selected as chemicals of potential concern for the J-Field shoreline.

The inorganic chemical analyses did not include cyanide. Cyanide was detected in 6/27 groundwater samples with a maximum concentration of 88 µg/L. If groundwater is discharging to surface water, cyanide could be present in surface water. As discussed previously, cyanide is likely to be present in groundwater as an iron-cyanide complex. Upon discharge to surface water bodies, photolytic reactions would liberate hydrogen cyanide from the iron cyanide complex. Thus, even tightly bound, low-toxicity iron-cyanide complexes in groundwater could be of concern if released to a surface water system, given the high toxicity of cyanide to aquatic life.

6.2.2.2 White Phosphorus Pits

Five inorganic chemicals (barium, magnesium, mercury, sodium, and zinc) were detected in samples from the white phosphorus pit surface water. All of these were detected at levels considered to be within the range of local background concentrations, and therefore, none were selected as chemicals of potential concern.

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[3] Brian Hughes, USGS, personal communication. October 1990.

6.2.3 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Table 6-4 summarizes the chemicals of potential concern for both surface water and groundwater at J-Field. A large number of organic and inorganic chemicals (principally metals) were selected as chemicals of potential concern in groundwater. Only metals and toluene were selected as chemicals of potential concern in surface water.

In addition to the chemicals of potential concern selected for each medium based on the available sampling data, other chemicals are likely to be present at J-Field and may be of potential of concern regarding possible exposures and impacts. Table 6-5 summarizes additional chemicals of concern potentially present at J-Field that either were not included in any of the chemical analyses (e.g., VX, chloroacetophenone); or were not analyzed for in specific media (e.g., organosulfur compounds and other degradation products in surface water, all persistent chemicals in soil). The chemicals listed are those that have the potential to be present in the greatest quantities based on historical information and on environmental fate characteristics. A large number of other chemicals could be present in smaller quantities at J-Field and therefore also could contribute to potential exposures and risks.

Lethal chemical agents, incapacitating agents, and incendiary materials are of potential concern because of the large quantities of these chemicals disposed of at J-Field. Munitions compounds could be present from past munitions testing at J-Field and from range tests at I-Field. Agent breakdown products (e.g., combustion products resulting from disposal activities and hydrolysis products resulting from environmental degradation) are of concern because of their potential contribution to groundwater, soil, and/or surface water contamination. Solvents are also of concern; given past methods of disposal, they could be present as free product in groundwater and subsurface soil, where they could act as a continual source of groundwater and surface water contamination.

6.3 HUMAN HEALTH RISK ASSESSMENT

This section addresses the potential human health risks associated with the J-Field study area in the absence of remedial actions. This human health risk assessment is divided into three principal sections. Section 6.3.1 evaluates potential human exposures for the chemicals of potential concern at the site. Section 6.3.2 summarizes relevant toxicity information for the chemicals of potential concern, and Section 6.3.3 provides estimates of human health risks.

6.3.1 EXPOSURE ASSESSMENT

This section identifies the pathways by which human populations may be exposed to chemicals of potential concern at or originating from J-Field and presents pathways selected for evaluation. Only complete pathways were selected for further evaluation (see Chapter 4 for a definition of a complete pathway). Evaluation of all potential exposures in this assessment was qualitative because of the low probability and magnitude of potential exposures and/or the limited availability of data to support quantitative evaluations.

This exposure assessment in organized into two principal sections. Section 6.3.1.1 discusses potential exposure pathways under current land-use conditions, and Section 6.3.1.2 discusses those potentially occurring under hypothetical future land-use conditions.

TABLE 6-4

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR J-FIELD

Chemical (a)	Groundwater	Surface Water
Organic Chemicals:		
Acetone (ACET)	X	
Benzene (C6H6)	X	
Chlorobenzene (CLC6H5)	X	
Chloroform (CHCL3)	X	
1,1-Dichloroethene (11DCE)	X	
1,2-Dichloroethene [Total] (12DCE)	X	
2,4-Dimethylphenol (24DMPN)	X	
1,4-Dithiane (DITH)	X	
Nitrobenzene (NB)	X	
1,4-Oxathiane (OXAT)	X	
p-Chlorophenylmethyl Sulfone (CPMSO2)	X	
Pentaerythritol Tetranitrate (PETN)	X	
Phenol (PHENOL)	X	
RDX	X	
1,1,2,2-Tetrachloroethane (TCLEA)	X	
Tetrachloroethene (TCLEE)	X	
Toluene (MEC6H5)		X
1,1,1-Trichloroethane (111TCE)	X	
1,1,2-Trichloroethane (112TCE)	X	
Trichloroethene (TRCLE)	X	
Vinyl Chloride (C2H3CL)	X	
Inorganic Chemicals:		
Arsenic (AS)	X	X
Cyanide (CYN)	X	
Fluoride (F)	X	
Lead (PB)	X	X
Mercury (HG)		X
Nickel (NI)		X
Nitrite/Nitrate (NIT)	X	
Selenium (SE)	X	
Sulfate (SO4)	X	X

(a) USATHAMA chemical codes listed in parentheses.

X = Selected as a chemical of potential concern.

Note: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium, (2) it was not included in the analyses, or (3) it was detected at background concentrations (inorganic chemicals only). See text for this information.

TABLE 6-5

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT J-FIELD (a)

Group	Chemical	Comments
Lethal Chemical Agents	Tabun (GA) VX Mustard	These chemicals have not been analyzed for in any medium at J-Field. Because they were tested or disposed of at J-Field, it is possible that they are still present to some extent at J-Field. However, it is unlikely that they are present in large quantites as a result of disposal given that incineration, the principal method of disposal, is believed to have been effective in destroying these agents. Tabun is not very volatile and does not hydrolyze rapidly, therefore it could persist in the environment and is possibly present in surface or subsurface soils near the toxic burn pits. VX is moderately persistent and is mobile and could be present in soils, groundwater and surface water of the area. Mustard could be present in soils near the toxic pits, although this is less likely. All of these agents also could exist in ordnance present from testing activities.
Incapacitating Agents	Adamsite (DM) Chloroacetophenone (CN) o-Chlorobenzylidene Malonitrile (CS)	These chemicals have not been analyzed for in any medium and were tested or disposed of at J-Field. DM could persist in soils near the riot control pits. CS is relatively insoluble and could persist in soils near the riot control pits. CN has a solubility comparable to the VOCs measured in groundwater at J-Field, and is relatively stable with respect to hydrolysis. Further, this chemical is unlikely to adsorb appreciably to soil and therefore could be present and mobile in groundwater. It also could be present and mobile in surface water.
Incendiary Materials	White Phosphorus (WP)	This chemical has been disposed of in large quantities at J-Field, and could be present in raw form in the subsurface soil and in sediments particularly in the Gunpowder River, which received drainage from WP pits in the past.
Munitions Compounds	TNT HMX RDX 2,4,6-Trinitrophenyl Methyl Nitramine Nitrobenzene 1,3-Dinitrobenzene Pentaerythritol Tetranitrate (PETN)	These and other chemicals were analyzed for in a limited number of groundwater samples at J-Field. Munitions testing has been conducted at J-Field, and these chemicals could be present in surface soil, groundwater, and surface water.
Agent Breakdown Products		Several of these products were analyzed for in groundwater only. They may be present as a result of combustion or hydrolysis of chemical agents which were disposed of in great quantities at J-Field by burning. They may be present in groundwater even though not detected in the limited number of samples analyzed, and may also be present in surface water and soils.
-- via hydrolysis	Hydrogen Cyanide	Product of: GA
	Isopropyl Methyl Phosphonic Acid	GB
	Methyl Phosphonic Acid	GB,VX
	Ethyl Methyl Phosphonic Acid	VX
	Thiodiglycol	Mustard
-- via combustion	Hydrogen Cyanide	Product of: GA
	1,4-Dithiane	Mustard
	1,4-Oxathiane	Mustard
Solvents	Trichloroethene and other chlorinated solvents	Although this chemical group was analyzed for in groundwater and surface water at the site, the extent of contamination could not be determined based on the limited number of samples. These chemicals were disposed of in large quantities and could be present as free product in groundwater, and to a lesser extent in surface water.
PCBs	Aroclor 1248	This chemical was not analyzed for in surface water, sediment, or soil as part of the USGS study. However, it was used as a heat transfer fluid in process pilot plant work at the Edgewood Area and possibly was disposed of at J-Field. It could be present in sediment, soil and surface waters (at low concentrations).

(a) Based on historical information. Chemicals listed are those potentially present in the greatest quantities. A large number of other chemicals could be present in smaller quantities at J-Field.

6.3.1.1 Potential Exposure Pathways Under Current Land-Use Conditions

Human use of J-Field is limited under current land-use conditions. Institutional and access restrictions are in place at the site. The J-Field area is located within a restricted section of the installation. Entry to this area is strictly controlled. The restricted area is subject to patrols by MPs and other armed security forces. In addition a wide variety of additional physical security countermeasures are employed to preclude unauthorized entry to this area.

The Robins Point demolition area is used approximately 100 days per year for a few hours a day. The toxic disposal pits and white phosphorus pits are used only rarely (once or twice a year) for emergency disposal operations. White phosphorus-contaminated soil or rounds found during construction operations are disposed of in the white phosphorus pits.

I-Field, located immediately north of J-Field, is used as an impact area. Tested items are fired into I-Field and then recovered. I-Field is used a little more than 1 week a month on average for an average of 6 hours per day.

Hunting and trapping are not allowed at J-Field. Migratory game bird hunting is approved for the shoreline around J-Field, but permits have not been issued for at least the last 5 years. Hunting and trapping are allowed in I-Field, which is located immediately north of J-Field. There are no areas in the J-Field study area that are approved for recreational fishing/crabbing from the shoreline. Fishing from boats occurs along the Gunpowder River and in the Chesapeake Bay near J-Field.

6.3.1.1.1 Potential Long-term Exposure Pathways Under Current Land-Use Conditions

Table 6-6 summarizes the current pathways by which humans could be exposed to chemicals at or originating from J-Field. Potential exposure pathways are discussed below by exposure medium.

Surface Soil. Exposure to chemicals in surface soil could occur via dermal contact and/or incidental ingestion. (Exposures to chemicals that are present on wind-blown dust or that volatilize from soil are discussed under the section on air.) No recent data are available on the levels of chemicals present in surface soils at J-Field. However, given past disposal activities, surface contamination is likely. Chemical concentrations are likely to be greatest in and near the toxic and riot-control agent disposal pits and trenches. Lower-level contamination could occur throughout J-Field as a result of particle deposition during past fires or explosions. Limited data from past studies (AEHA 1989; Princeton Aqua Science 1984 in AEHA 1989) report elevated levels of silver, barium, cadmium, chromium, and lead in J-Field soil. DDT and its metabolites, PCBs and PAHs, also were detected.

The only personnel potentially exposed via direct contact at this time are involved in ordnance disposal activities at the Robins Point demolition area or occasional emergency white phosphorus or toxic disposal activities. Although the potential for significant soil contamination exists (particularly in the disposal areas), significant exposures under current use conditions are unlikely because these activities do not involve direct contact with soil. Personnel engaged in these activities are aware of the potential hazards at J-Field and likely wear protective clothing and take other precautions to avoid accidental contact with soil. These factors, combined with the infrequent use of J-Field by workers, likely results in negligible exposures. Therefore, this pathway was not selected for evaluation.

Subsurface Soil. Exposure to chemicals in subsurface soil could occur via dermal contact and/or incidental ingestion during activities such as excavation. Chemical concentrations in

TABLE 6-6

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT J-FIELD

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Soil	Dermal contact and/or incidental ingestion of soil by personnel occasionally working at J-Field.	Negligible. Access to J-Field is restricted. Personnel involved in disposal activities are unlikely to significantly contact soil and most likely wear some type of protective clothing during these activities. Further, these personnel are present at J-Field infrequently and for short periods of time.	Poor. No soil data collected as part of USGS study. Limited sampling data collected as part of other studies.	None, due to low potential for exposure and limited data.
Subsurface Soil	None. Although subsurface soils are likely to be contaminated as a result of past waste disposal, no activities that involve potential contact with subsurface soil (e.g., excavation) take place at J-Field.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Groundwater	None. Although chemical transport to groundwater from sources has occurred, there are no human uses of groundwater at the site or in downgradient areas.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Surface Water/ Sediment	None. Although chemicals in groundwater may be discharging to surface water, the limited activities at J-Field do not involve contact with surface water or sediment. Nearby surface waters are not used as a source of drinking water nor are they used for swimming.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Fish	Ingestion by local fishermen of fish that have accumulated chemicals from the Gunpowder River or the Chesapeake Bay near J-Field.	Negligible. Most of the chemicals detected in surface water do not accumulate in fish to any great extent. Further, significant accumulation is not likely given the large foraging areas and habitat preferences of the types of fish likely to be caught in the Gunpowder River and Chesapeake Bay and eaten by fishermen.	Poor. No fish tissue data available for fish in Gunpowder River.	None, due to low potential for exposure.

See footnotes on the following page.

TABLE 6-6 (Continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT J-FIELD

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Game	Ingestion of game that has accumulated chemicals from J-Field by persons hunting at I-Field.	Negligible. Hunting does not occur at J-Field but does occur but does occur at I-Field. Game species at I-Field could spend some time at J-Field. Chemicals that could accumulate in game have been detected at J-Field but are unlikely to be widespread. Therefore, significant chemical accumulation in game at I-Field is very unlikely.	Poor. No tissue samples available and very limited information on extent of contamination for chemicals that could bioaccumulate in game.	None, due to low potential for exposure.
Air/Vapors	Inhalation by workers of vapors that have volatilized from the subsurface at J-Field.	Moderate. Volatile chemicals in groundwater, subsurface soil, or wastes could be transported to air via migration through soil.	Poor. No air data available. Available soil gas data cannot be used to estimate concentrations.	Qualititative, due to lack of data.
Air/Vapors	Inhalation by workers of vapors that have volatilized from surface water at J-Field.	Moderate. Groundwater is contaminated and it is likely that it discharges to surface water, although the discharge point is unknown.	Poor. No air data available. Too few surface water samples collected to model volatile emissions from surface water.	Qualitative, due to limited data.
Air/Dust	Inhalation by workers of dust that has eroded from surface soil at J-Field.	Moderate. Dust generation and transport is possible because the areas most likely to be contaminated are sparsely vegetated. High soil moisture content may mitigate dust generation somewhat.	Poor. No air data available. No soil data collected as part of USGS study. Limited soil data available from other studies.	Qualitative, due to limited data.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.
NA = Not applicable.

subsurface soils are not known, but the potential for significant contamination exists. However, no activity that involves contact with subsurface soils occurs at J-Field. Therefore, no complete exposure pathway exists under current land-use conditions.

Groundwater. There are no human uses of groundwater from the site or in downgradient areas. Therefore, although chemical transport to groundwater from sources has occurred, no complete groundwater exposure pathways exist under current land-use conditions.

Surface Water/Sediment. Direct human exposures to chemicals in J-Field surface waters/sediments is not likely under current land-use conditions. Adjacent surface waters are brackish (salinity is approximately 2-8 ppt) and are not used as a source of potable water. People do not swim in the Gunpowder River near J-Field and are unlikely to contact chemicals in surface water or sediment while fishing in the river. Therefore, direct contact and direct ingestion exposures to chemicals in surface water/sediment are not likely under current land-use conditions. This pathway was not selected for evaluation.

Fish. It is possible that individuals fishing in the Gunpowder River and Chesapeake Bay could be exposed to chemicals by the consumption of fish that have accumulated chemicals from surface water or sediment. Of the chemicals of potential concern in J-Field surface water, mercury has the greatest potential to bioaccumulate in fish. If mercury bioaccumulation is occurring, it would be greatest in fish that spend all of their time along the J-Field shoreline, and less in fish that spend no time or only a portion of their time near the shore.

Assuming that the contaminated area and the surrounding area provide equally suitable habitat for a particular fish species, the amount of time a given fish spends in a contaminated area depends upon the size of the area and the size of the fish's foraging or home range area. Because many of the fish species of commercial and recreational importance at APG tend to be larger species (e.g., white perch, channel catfish) likely to forage over large areas, they are unlikely to spend all of their time in one area, such as the J-Field shoreline.

It is difficult to predict potential bioaccumulation in fish species when the contaminated area is an "open system," and fish can move in and out of a contaminated area. Typically, bioaccumulation in fish is estimated using simple models (i.e., using bioconcentration factors) that assume continuous exposure of the fish to a constant chemical concentration and equilibrium partitioning of a chemical between the fish (or fish tissue) and water. However, such conditions would not occur if fish can move in and out of the contaminated area, as is the case of the commercial and recreational fish species in the J-Field area. Therefore, partitioning models typically used to evaluate bioaccumulation are not appropriate.

Since commercial and recreational fish species in the area are unlikely to spend significant portions of their time immediately along the J-Field shoreline, fish caught in the Gunpowder River or Chesapeake Bay near J-Field have probably not accumulated significant quantities of mercury from surface water along the J-Field shoreline. Therefore, the potential magnitude of exposure for this pathway is low, and this pathway was not selected for evaluation. If contamination associated with J-Field extended a significant distance into the Chesapeake Bay, there could be a greater potential for accumulation in fish from the area.

Game. No hunting is allowed at J-Field, but it is allowed in I-Field directly north of J-Field. Conceivably, deer, waterfowl, and other game animals could be exposed to chemicals present at J-Field (e.g., via drinking water, ingestion of food) and be killed by individuals hunting at I-Field and consumed. Generally, potential accumulation in terrestrial food chains is associated with nonpolar, fat-soluble chemicals such as PCBs, dioxins, or organochlorine pesticides. PCBs and DDT have been detected in soils at J-Field but the extent of contamination by these compounds is currently unknown. Based on historical information, if PCB, DDT or similar contamination exists at J-Field, it is most likely to be limited to small areas around the disposal pits. This type of localized contaminant distribution is unlikely to result in any accumulation in game species at I-Field that would spend only a small portion of their time at J-Field. For this reason and because people are unlikely to consume large quantities of game from I-Field, this pathway likely results in negligible exposures. It was not selected for evaluation in this assessment.

Air. Air contamination at J-Field can result from direct volatilization of chemicals and transport by wind entrainment of chemicals present on dust particles. (Atmospheric dispersal of contaminants due to an explosion or fire is discussed in the section on acute exposures.)

Migration of contaminants by wind entrainment of dust particles may be an important transport process at J-Field, because the areas with the greatest potential for wind erosion are bare soils associated with disposal sites. The disposal sites also are likely to be the most contaminated. Additionally, because of the somewhat exposed location of J-Field at the end of the peninsula, portions of the site are open to winds from the Chesapeake Bay. These effects may be mitigated somewhat by the high moisture content probably associated with J-Field soils for all or most of the year.

Release of volatile chemicals to the atmosphere at J-Field can occur as a result of groundwater discharge to surface water with subsequent volatilization or as a result of volatilization in subsurface environments (from subsurface soil, waste, or groundwater) and transport through soil spaces to the atmosphere. Because groundwater is contaminated with volatile organic chemicals and discharges to surface water, volatile releases to the air from surface water are likely. Gas migration through soil also is likely. A soil gas survey by Northeast Research, Inc. (NERI 1989) indicates that trichloroethene, tetrachloroethene, alkanes, aromatics, and hydrocarbons are being emitted from soil in the toxic pit area. (The gas survey measured chemical flux rates, not concentrations, so exposure estimates cannot be derived.)

Chemicals present on dust or volatilizing from surface water or the subsurface environment could reach potential receptors if they are dispersed through the atmosphere from the emission source to potential receptors, resulting in inhalation exposures. At the present time, the only persons who spend time at J-Field are APG personnel involved in disposal activities at Robins Point or in the white phosphorus or toxic pits areas. Because of their proximity to potential emission sources, the potential for significant inhalation exposures exist. Therefore, this pathway was evaluated. A qualitative evaluation of worker exposure was conducted because too few data are available to reliably model such exposures.

6.3.1.1.2 Potential Acute Hazards Under Current Land-Use Conditions

Explosive, incendiary, and chemical-filled munitions may be present at J-Field given its proximity to the firing range impact area at I-Field and its prior use as a chemical agent rocket test site. Detonation of unexploded ordnance or munitions present beneath the soil surface could occur during activities such as digging or excavation. However, disposal practices at J-Field (high-explosive detonation and burning of wastes) do not involve digging. Therefore, this scenario is very unlikely to occur, and the exposure pathway was not evaluated.

6.3.1.2 Potential Exposure Pathways Under Future Land-Use Conditions

It is unlikely that the use of J-Field will change in the future. It is most likely to continue to be an ordnance disposal and toxic waste disposal area. Other uses of the area (e.g., as an industrial area) are unlikely given J-Field's location and past use as a firing range impact area and chemical agent rocket test site.

Exposures to chemicals in subsurface soils and groundwater are not considered likely under any reasonable future-use scenario. Excavation of subsurface soils (other than for remediation) is highly unlikely given the known hazards that exist at J-Field. Use of groundwater also is not considered plausible given the institutional controls at APG, as well as the institutional knowledge of the contaminated nature of the groundwater at J-Field.

It is conceivable, although probably unlikely, that the Gunpowder River near J-Field could be used for swimming in the future. Persons swimming in the Gunpowder River could be directly exposed to chemicals in surface water via dermal absorption and via incidental ingestion of surface water. Although unlikely, this is the only exposure pathway considered reasonably plausible under future use and was thus selected for evaluation. This pathway was evaluated qualitatively given its low probability of occurring in the future. This future use is summarized in Table 6-7.

6.3.2 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria was described in Chapter 4 to provide the analytical framework for the characterization of human health impacts.

Toxicity summaries for all chemicals of potential concern are provided in Appendix B. Because no human health pathways were selected for quantitative evaluation, chemical-specific toxicity criteria are not presented here. However, the risks associated with exposure to these chemicals are discussed qualitatively in the following section.

6.3.3 RISK CHARACTERIZATION

In this section, the human health risks associated with J-Field are evaluated. Potential risks under current land-use conditions are presented in Section 6.3.3.1, and those under hypothetical future land-use conditions are presented in Section 6.3.3.2. Risks under both current and hypothetical future land-use conditions were evaluated qualitatively.

6.3.3.1 Potential Risks Under Current Land-Use Conditions

The exposure pathways selected for qualitative evaluation under current land-use conditions are:

- Inhalation by workers of vapors that have volatilized from soil at J-Field;
- Inhalation by workers of chemicals that have volatilized from nearby surface water; and
- Inhalation by workers of dust that has eroded from surface soil at J-Field.

JF-FPATH

TABLE 6-7

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER HYPOTHETICAL FUTURE LAND-USE CONDITIONS AT J-FIELD

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposures (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Water	Dermal contact and incidental ingestion by persons swimming in the Gunpowder River.	Negligible to moderate. The principal chemicals in Gunpowder River surface water are metals, which are not dermally absorbed to any appreciable extent. Exposures could occur through incidental ingestion. However, it is considered unlikely that the Gunpowder River near J-Field would be used in the future for swimming.	Poor. Too few surface water samples collected to give an accurate representation of water concentrations in the Gunpowder River or Chesapeake Bay.	Qualitative, due to limited data and small likelihood that use will change in the future.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.

Risks to workers from inhalation of chemicals present in air as a result of volatilization or windblown dust cannot be quantified because information is incomplete on the extent of surface water, surface soil, and subsurface contamination. However, there is probably some contaminant transport via these pathways at J-Field. For example, the presence of volatile organic chemicals in groundwater underlying J-Field and in a soil vapor survey suggest that volatile organic chemicals are probably being transported through surface soil. Furthermore, it is also likely that volatile organic chemicals in groundwater are being discharged to surface water. Some dust transport also is likely given that the disposal pits are not vegetated. Because human activities at J-Field are infrequent and short in duration, the potential for significant worker exposures and risks is probably low. However, if chemicals are being released in significant quantities, human health risks are conceivably possible, even with the low duration and frequency of exposure. Risks associated with these pathways cannot be evaluated more completely at this time.

6.3.3.2 Potential Risks Under Hypothetical Future Land-Use Conditions

Under hypothetical future land-use conditions, it is possible that the Gunpowder River could be used for recreational purposes. Individuals swimming off the J-Field shoreline could be exposed to chemicals via dermal contact and incidental ingestion of water, but too few surface water data are available to assess the risks. The greatest source of risk is exposure to arsenic in surface water via incidental ingestion. Arsenic, a known human carcinogen with a relatively high cancer slope factor of 2.0 $(mg/kg\text{-}day)^{-1}$, is the most toxic of the chemicals detected in J-Field surface water. However, exposure to arsenic while swimming is unlikely to pose a significant risk. For example, a person who swam along the J-Field shoreline every day of his 70-year life and incidentally ingested 100 ml of water each day while swimming would experience only a 2×10^{-7} excess lifetime cancer risk if exposed to the maximum detected concentration of 5 µg/L. Dermal exposure would contribute negligibly because metals are not appreciably absorbed through the skin.

6.4 ECOLOGICAL ASSESSMENT

This section assesses potential ecological impacts associated with the chemicals of potential concern at the J-Field study area in the absence of remediation. The methods used to assess ecological impacts follow those outlined in Chapter 4 and roughly parallel those used in the human health risk assessment. Below, potentially exposed populations (receptors) are identified. Then information on exposure and toxicity is combined to derive estimates of potential impact in these populations. It is emphasized that this ecological assessment is a predictive assessment. Comprehensive field studies of ecological impacts have not yet been conducted at J-Field. Furthermore, given the limited sampling data available to date, this assessment should be considered largely preliminary.

This ecological assessment is divided into four principal sections. Section 6.4.1 describes the habitat of the area and identifies the potential receptor species or species groups selected for evaluation. Section 6.4.2 evaluates and provides estimates of potential exposures for the chemicals and receptors of potential concern. Section 6.4.3 summarizes relevant toxicity information for the chemicals of potential concern, and Section 6.4.4 provides estimates of ecological impact.

6.4.1 RECEPTOR CHARACTERIZATION

J-Field is a mixture of upland forests interspersed with seasonal palustrine forested wetlands, tidal emergent wetlands, and scarred bare earth associated with the disposal pits and trenches. A significant portion of the eastern and southern shore of J-Field is composed of tidal wetlands. Surface water in the study area consists of the Gunpowder River to the west, the Chesapeake Bay to the south and east, and a moderate-size pond within the tidal wetland bordering the Chesapeake Bay. Some small ponds of standing water occur in the white phosphorus pits. Figure 6-2 presents some of the principal habitat characteristics at J-Field and the surrounding area.

The study area likely supports a variety of wildlife species, given the presence of forest and wetland habitats. Typical forest species of the area probably include the gray fox (*Urocyon cinereoargenteus*), gray squirrel (*Sciurus carolinensis*), deer (*Odocoileus virginianus*), and woodpeckers (*Dendrocopos* spp.). Field mice (*Peromyscus leucopus*, *Mus musculus*), voles (*Microtus* spp.) rabbits (*Sylvilagus floridanus*), mourning doves (*Zenaidura macroura*), killdeer (*Charadrius vociferus*), hawks (*Buteo jamaicensis*, *Circus cyaneus*), and a variety of song birds probably inhabit the forest edge areas. Wetland species likely include the muskrat (*Ondatra zibethicus*), great blue heron (*Ardea herodias*) and other wading bird species, mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*) and other dabbling ducks, and a variety of shorebirds, including spotted sandpipers (*Actitis macularia*), yellowlegs (*Tringa* spp.), and rails (*Rallus* spp.). Raccoons are likely to be present through J-Field, particularly in the forested wetlands. Bald eagles (*Haliaeetus leucocephalus*) forage in area.

The Gunpowder River provides aquatic habitat for a variety of freshwater and estuarine aquatic life. Freshwater and estuarine fish that are likely to be present include largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), black drum (*Pogonias cromis*), carp (*Cyprinus carpio*), white perch (*Morone americana*), striped bass (*Morone saxatilis*), yellow perch (*Perca flavenscens*), bluefish (*Pomatomus saltatrix*), and Atlantic silverside (*Menidia menidia*) (AEHA 1978, 1985). Other fish species found year round or seasonally in the Gunpowder River include channel catfish (*Ictalurus* punctatus) and various species of herrings (*Alosa* spp., *Anchoa mitchilli*, *Brevoortia tyrannus*). A variety of benthic invertebrate species are likely to inhabit the sediments of the wetlands, the Gunpowder River, and the Chesapeake Bay.

As discussed in Chapter 4, it is not feasible to assess potential impacts in each of the species potentially present at J-Field, and for this reason indicator species or species groups are selected for further evaluation. The selection of indicator species for the J-Field study area is driven by several factors including the potential for exposure, the sensitivity of susceptibility to chemical exposures, the availability of chemical data for potential exposure media, ecological significance, and societal value. The indicator species or species groups selected for evaluation at J-Field based on these considerations are a subset of those identified as potential indicators in Chapter 4 and are listed below along with the rationale for their selection.

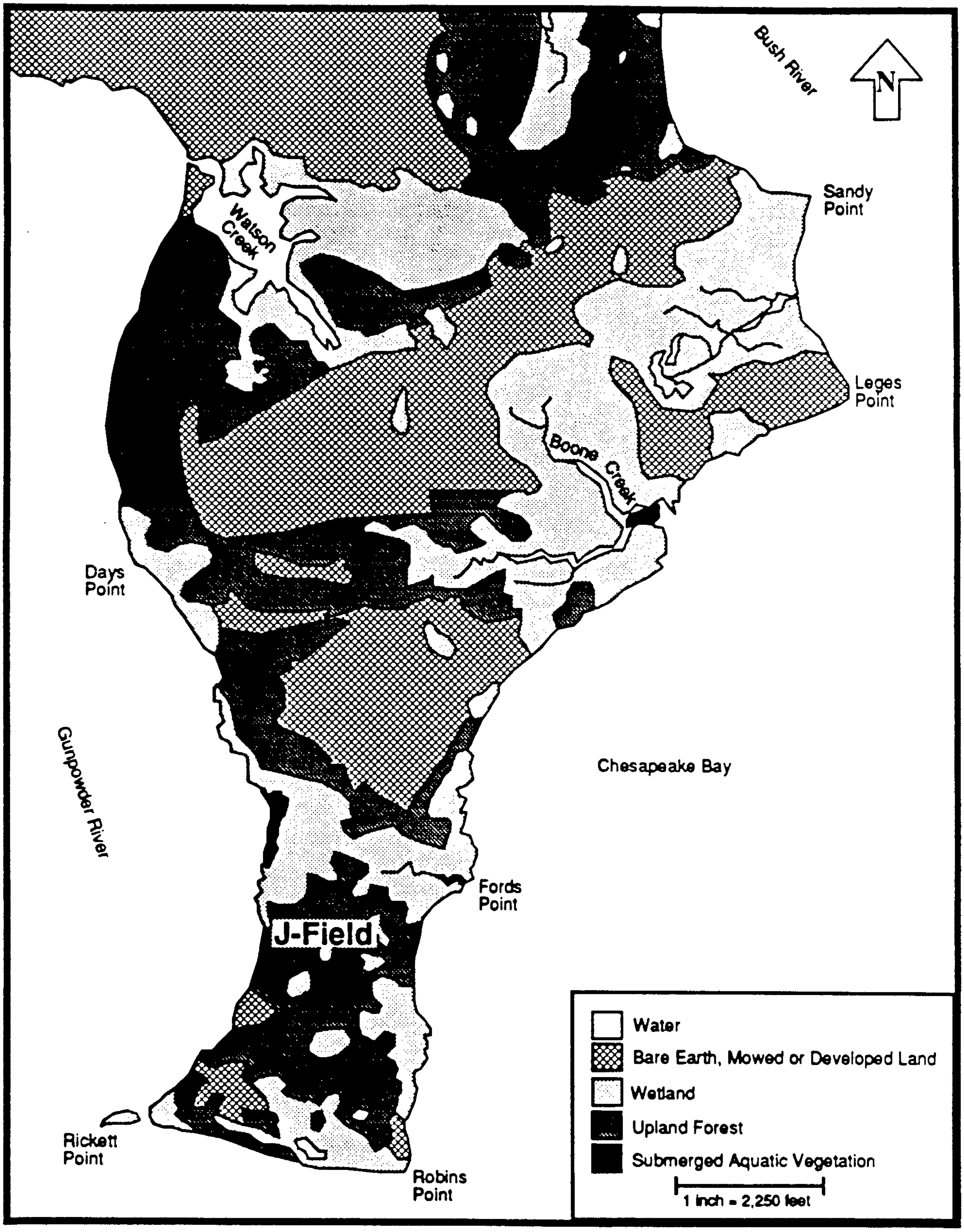
<u>Aquatic Species</u>

Fish:

- Striped bass. This species was selected for evaluation because surface waters surrounding Gunpowder Neck are used as a nursery area and feeding ground. Furthermore, striped bass are a commercially important species whose declining populations resulted in closure of the fishery until recently.

Figure 6-2

Habitat Characteristics of the J-Field Study Area At Aberdeen Proving Ground



F0D059-2

- White perch. White perch were selected because of their ecological and commercial importance. Juvenile white perch are prey for yearling and older striped bass, and impacts to this species could affect striped bass populations. White perch are an important commercial and sport fish.

- Herrings. This species group was selected for evaluation because juveniles of several members of this family could use the Gunpowder River as a nursery area (i.e., blueback herring, alewife, menhaden) and thus are vulnerable to population impacts due to juvenile mortality. Furthermore, several species within this family are commercially important.

Invertebrates:

- Benthic invertebrates. This species group was selected because they are susceptible to exposures to chemicals being released from groundwater to surface water through sediments. They also are an important component of the diet of many birds, as well as adult and juvenile fish.

Terrestrial Species

Birds:

- Spotted sandpiper. This species was selected for evaluation because of its probable frequent use of J-Field and its susceptibility to exposure to chemicals in the wetlands and along the shoreline of J-Field. Sandpipers feed principally on insects (aquatic larvae and adults). Some of the metals detected in surface water can bioaccumulate in aquatic insects.

The other species listed in Chapter 4 as potential indicator species were not selected for evaluation at J-Field because (1) J-Field does not provide optimal or preferred habitat, (2) data for media in their particular habitat are not available, or (3) exposure in the other receptor species is likely to be less than or equal to that in the selected receptor species.

Appendix D provides species profiles for the vertebrate species selected for evaluation. These profiles should be consulted for information on the ecology of the selected indicator species. Such profiles are not provided for benthic invertebrates due to the large diversity of species comprising this broadly defined receptor group.

6.4.2 POTENTIAL EXPOSURE PATHWAYS AND QUANTIFICATION OF EXPOSURE

In this section, the potential pathways by which the selected indicator species and species groups could be exposed to the chemicals of potential concern at J-Field are discussed, and exposure is quantified for selected exposure pathways. This exposure assessment focuses on potential exposures to chemicals in surface water. No pathways exist by which wildlife could be exposed to chemicals of potential concern in groundwater[4], and data regarding chemical concentrations in surface and subsurface soils, sediment, and surface water in the marshes and wetlands are not available.

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[4] Groundwater released to surface water is evaluated as surface water exposure.

Potential exposures were evaluated separately in the following sections for aquatic and terrestrial receptors. For both aquatic and terrestrial wildlife exposures, it is assumed that all mercury in surface water near J-Field is in the inorganic form. It is recognized that inorganic mercury present in sediments can be methylated by microorganisms to methylmercury. However, a review of the literature on mercury levels in sediments shows that organic mercury is normally 0.01-1% of the total mercury concentration in freshwater and marine sediments (Stary et al. 1980, Battelle 1987) and that total mercury concentration is virtually an estimate of inorganic mercury concentrations (Jackson 1986).

6.4.2.1 Aquatic Life Exposures

As discussed in Chapter 4, aquatic life could be exposed to chemicals in surface water and sediment by several pathways. However, most available aquatic toxicity data express toxicity as a function of the concentration in the exposure medium (i.e., surface water or sediment concentration). To be consistent with available toxicity data, exposures to aquatic life were evaluated in this assessment by using surface water concentrations for the Gunpowder River and the Chesapeake Bay directly south of the site.

The exposure point concentrations for chemicals in surface water are the lower value of the 95% upper confidence limit on the arithmetic mean or the maximum detected concentrations. The surface water exposure point concentrations are presented in Table 6-8.

It is likely that groundwater discharges into the surface water near J-Field. However, discharge points are not known, and the current understanding of groundwater flow beneath J-Field is inadequate to hypothesize such discharge points. Based on current data, concentrations of volatile organic chemicals in groundwater appear to be low, with maximum detected concentrations ranging from 2.5 to 150 µg/L. If groundwater discharges into surface water at J-Field, benthic species in surface water near the point of discharge could be exposed to volatile organic chemical concentrations equivalent to those occurring in groundwater as it discharges directly through the sediments. Exposures in water column species would be less. However, aquatic life exposures as a result of groundwater discharge cannot be evaluated with the available data.

6.4.2.2 Terrestrial Wildlife Exposures

As discussed in Chapter 4, terrestrial wildlife could be exposed to chemicals in surface water and sediment by a variety of pathways. However, adequate data are not available to assess wildlife exposures via all pathways, and therefore, only exposures via ingestion of surface water and food were selected for consideration in the ecological assessments for the various APG study areas. For this assessment of J-Field, only ingestion of contaminated food was evaluated. Ingestion of surface water was not selected for evaluation because it is likely to be an insignificant pathway compared to the ingestion of food that has accumulated chemicals at concentrations greater than those in the surrounding media.

The spotted sandpiper was selected as the terrestrial indicator species for this assessment. This species is an aquatic insectivore, feeding predominantly on sediment-dwelling invertebrates. Spotted sandpipers are likely to feed in the marshes and shoreline at J-Field. Small crustaceans, marine worms, and aquatic insects are likely the principal components of their diet. This assessment

TABLE 6-8

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AT J-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
J-FIELD SHORELINE				
Arsenic (AS)	1.9	2.2	5.0	2.2
Lead (PB)	4.4	7.2	25	7.2
Mercury (HG)	0.2	0.3	0.5	0.3
Nickel (NI)	11	13	33.7	13
Sulfate (SO4)	590,000	720,000	660,000	660,000
Toluene (MEC6H5)	--	--	3.1	3.1

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

evaluated sandpiper exposure via ingestion of organisms that have accumulated chemicals from surface water near J-Field.

Chemical concentrations in invertebrates living along the J-Field shoreline are estimated in this assessment using bioconcentration factors (BCFs) and chemical concentrations in surface water. Bioconcentration factors provide a measure of the extent of chemical partitioning at equilibrium between a biological such as invertebrates and an external medium such as water. For most chemicals and most situations, water is considered to be the predominant source of chemical residues in aquatic organisms (Neff 1979).[5] Use of the BCFs to estimate chemical concentrations in aquatic life is therefore a reasonable approach in the absence of measured tissue concentrations.

Information on the bioconcentration potential of the chemicals of potential concern in surface water from the Gunpowder River and Chesapeake Bay was obtained from the available literature. A summary of bioconcentration data for the chemicals of potential concern is presented in the chemical-specific ecological toxicity profiles in Appendix C. In selecting BCFs for use in this risk assessment, the following screening procedures were used.

- Data from laboratory studies were generally used in preference to field data because laboratory studies involve considerably greater control of the parameters affecting bioaccumulation (e.g., chemical concentration, exposure duration). Field data were used only if no laboratory data were available.

- The highest BCF reported in the literature for insects, small crustaceans, or marine worms was selected for use in this assessment.

Exposures of sandpipers to chemicals in invertebrates were evaluated only for chemicals with invertebrate:water BCFs greater than 300. As discussed in Chapter 4, BCFs greater than 300 generally are considered to result in significant bioaccumulation in aquatic life (EPA 1989). A BCF for lead of 1,120 is reported for the stonefly larvae following 28 days of exposure (Spehar et al. 1978 in EPA 1985a), and a BCF of 14,360 is reported for the copepod *Acartia clausi* following 24 hours of exposure to mercury (Eisler 1987). BCFs for the four remaining chemicals of potential concern are not presented for the following reasons: BCFs for arsenic and nickel are below 300, volatile organic compounds such as toluene show little tendency to bioaccumulate, and no BCFs are available for sulfate. Available toxicity data for each of the chemicals of potential concern are presented in Appendix C.

Chemical concentrations in invertebrates were estimated using the selected BCF and the measured surface water concentrations in an equilibrium-partitioning model:

$$C_I = C_w * BCF_{I:w} \qquad \text{(Eq. 1)}$$

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[5] The principal exceptions to this are highly hydrophobic organic compounds such as PCBs, dioxins, and DDT.

where

C_i = chemical concentration in invertebrates (mg/kg);

C_w = chemical concentration in the water column (mg/L)

$BCF_{i:w}$ = invertebrate:water BCF (mg/kg food per mg/L water).

For chemical concentrations in water, the total chemical concentration was used, because information on dissolved chemical concentrations is not available. This resulted in overestimates of exposure because chemicals sorbed onto particles are not available for uptake by aquatic invertebrates. The RME concentrations reported in Table 6-8 were used to estimate concentrations in aquatic invertebrates.

Exposure of the spotted sandpiper via ingestion of contaminated benthic invertebrates is estimated using the following equation:

$$Dose = C_i * FI_i / BW \tag{Eq. 2}$$

where

Dose = exposure (mg/kg bw);

C_i = concentration in invertebrates (mg chemical/kg insect);

FI_i = daily intake of invertebrates from the J-Field shoreline (kg); and

BW = body weight (kg).

For this assessment, sandpipers were assumed to weigh 43 g (0.043 kg) and ingest 7.5 g (0.0075 kg) of food each day, all of which was assumed to be aquatic invertebrates (see Appendix D for source of values). Sandpipers were further assumed to obtain 50% of their daily insect intake, or 3.8 g (0.0038 kg), from the J-Field shoreline. This is a reasonable and perhaps conservative assumption, given the wide availability of suitable sandpiper habitat in the areas surrounding J-Field and the fact that sandpipers consume flying (adult) insects in addition to aquatic invertebrates.

The resulting estimates of exposure are presented in Table 6-9.

6.4.3 TOXICITY ASSESSMENT

The general methodology for the development of toxicity values for the evaluation of ecological impacts has been described in Chapter 4. The toxicity values used to evaluate aquatic life and terrestrial wildlife impacts are presented in this section along with a brief description of the basis of each value. Table 6-10 presents acute and chronic toxicity values for the assessment of aquatic life impacts from exposure to chemicals of potential concern in surface water. Table 6-11 presents toxicity values for the assessment of impacts to spotted sandpiper feeding at J-Field. Appendix C presents complete ecological toxicity summaries for all chemicals of potential concern for which exposures were evaluated.

TABLE 6-9

ESTIMATED EXPOSURES IN SPOTTED SANDPIPERS INGESTING AQUATIC INVERTEBRATES THAT HAVE ACCUMULATED CHEMICALS FROM SURFACE WATER NEAR J-FIELD

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg invertebrate per mg/L water)	Estimated Concentration in Invertebrate (mg/kg invertebrate)	Estimated Dose (mg/kg bw) (b)
Lead	0.0072	1,120	8	0.71
Mercury	0.0003	14,360	4	0.38

(a) Reported previously in Table 6-8.
(b) Calculated assuming a sandpiper weighs 0.043 kg and ingests 3.8 g (0.0038 kg) of aquatic invertebrates from surface water near J-Field each day.

TABLE 6-10

TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT J-FIELD

Chemical (a)	Acute Toxicity Value (ug/L) (b)	Basis for Value (c)	Chronic Toxicity Value (ug/L) (b)	Basis for Value (c)
Arsenic III (ASIII)	69	AWQC (saltwater); EPA (1985b)	36	AWQC (saltwater); EPA (1985b)
Arsenic V (ASV)	850	LOEC in freshwater species; EPA (1985b)	13	LOEC for saltwater species; EPA (1985b)
Lead (PB)	150	AWQC (saltwater); EPA (1985a)	5.6	AWQC (saltwater); EPA (1985a)
Mercury (HG)	2.2	LOEC in freshwater species; (EPA 1985c)	0.26	Chronic value for fathead minnow; EPA (1985c)
Nickel (NI)	75	AWQC (saltwater); EPA (1986a)	8.3	AWQC (saltwater); EPA (198a)
Sulfate (SO4)	190,000	LC50 in diatoms; factor of 10 applied to account for inter-species variation; Patrick et al. (1968)	76,000	Estimated chronic value; extrapolated from an LC50 for diatoms by applying an ACR of 25; Patrick et al. (1968)
Toluene (MEC6H5)	641	Lowest LC50 in 5 freshwater species; Galassi et al. 1988 in AQUIRE (1990)	25	Chronic value for rainbow trout; Black et al. (1982) in AQUIRE (1990)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more study details.

ACR = Acute to chronic ratio.
AWQC = Ambient Water Quality Criteria.
LOEC = Lowest-observed-effect concentration.

TABLE 6-11

TOXICITY VALUES FOR ASSESSMENT OF IMPACTS IN SPOTTED SANDPIPER FROM EXPOSURE TO CHEMICALS AT J-FIELD

Chemical (a)	Toxicity Value (mg/kg bw) (b)	Basis for Value (c)					
		Test Species	Exposure Duration	Dose (mg/kg bw)	Effect	Source	Uncertainty Factor
Lead (PB)	1.2	Kestrel	7 Months	12 (d)	NOAEL	Pattee (1984)	10 (to account for interspecies variation)
Mercury (HG)	0.41	Chicken, turkey, pheasant, duck	Not reported	0.41 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)

(a) USATHAMA chemical codes listed in parentheses.

(b) Derived using methodology outlined in Chapter 4.

(c) See Appendix C for additional information on the referenced studies.

(d) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages using the dietary conversion factors reported in Lehman (1954). See Appendix C for more detail.

6.4.4 ESTIMATES OF IMPACT

Impacts to aquatic and terrestrial wildlife exposed to chemicals of potential concern at J-Field were evaluated by comparing estimated exposures with the appropriate toxicity value for the chemical and receptors of concern. Exposures that exceed the selected toxicity value suggest that impacts may be possible in the evaluated species or similar species. Potential impacts to aquatic life are discussed below in Section 6.4.4.1, and those to terrestrial wildlife are discussed in Section 6.4.4.2.

6.4.4.1 Potential Impacts in Aquatic Life

Exposures of aquatic life to chemicals in water from the Gunpowder River and the Chesapeake Bay were evaluated by comparing measured surface water concentrations with the selected acute and chronic toxicity values. This comparison is presented in Table 6-12. As the comparisons on this limited set of chemicals indicate, surface water concentrations of some chemicals exceed chronic toxicity values for aquatic life. Based on these comparisons, it is possible that aquatic organisms in surface water near J-Field are being impacted; it should be stressed, however, that these are preliminary findings based on a limited set of monitoring data.

It is likely that organic chemicals in groundwater are being discharged to surface water. The concentrations of organic chemicals in groundwater are relatively low, but conceivably could result in impacts if these compounds act additively. Abernethy et al. (1988) provided some data to suggest that many non-ionizable organic chemicals, such as those in groundwater at J-Field, can act additively. Aquatic organisms at J-Field could therefore be impacted by the release of volatile organic chemicals from groundwater, particularly at the site of discharge.

Aquatic life also may be impacted by the release of cyanide from groundwater to surface water. Cyanide was detected in groundwater at concentrations between 11 and 88 µg/L, but was not analyzed for in surface water. Cyanide is very toxic to aquatic life. The ambient water quality criteria for the protection of aquatic life is 5.2 µg/L for chronic exposures and 22 µg/L for acute exposures (EPA 1986b). Based on the measured concentrations in groundwater, the potential exists for cyanide-induced toxicity in aquatic life in the receiving waters.

Any impacts associated with groundwater release to surface water are probably greatest in the area of groundwater discharge, since this area is likely to have the highest concentrations of volatile organic chemicals being released to surface water. Further analysis of potential impacts is not possible based on the currently available data.

Aquatic organisms in the wetlands and marshes are probably more susceptible to impacts from site-related chemicals, because these areas are more static, with slower flow rates and less dilution than the Gunpowder River or Chesapeake Bay. Again, a more definitive characterization of potential impacts is not possible unless additional data are collected.

Based on these preliminary data and findings, it is not known whether acute and chronic toxicity in J-Field surface waters are impacting the aquatic communities in the Gunpowder River and the Chesapeake Bay. Because these surface waters serve as a nursery area for striped bass, white perch, and blueback herring, larvae and juveniles of these species could be susceptible to reductions in survival and growth if they are being exposed to chemicals in the Gunpowder River. However, because the Gunpowder River near J-Field provides nursery habitat for only a small proportion of the total population of these species in the Chesapeake Bay, such impacts alone are unlikely to have

TABLE 6-12

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS FOR CHEMICALS IN GUNPOWER RIVER AND CHESAPEAKE BAY NEAR J-FIELD

(Concentrations reported in ug/L)

Chemical (a)	Toxicity Value (b)		Exposure Concentration (c)	Toxicity Value Exceeded
	Acute	Chronic		
Arsenic - III (ASIII)	69	36	2.2	--
Arsenic - V (ASV)	850	13		
Lead (PB)	150	5.6	7.2	Chronic
Mercury (HG)	2.2	0.26	0.3	--
Nickel (NI)	75	8.3	13	Chronic
Sulfate (SO4)	190,000	76,000	660,000	Acute/ Chronic
Toluene (MEC6H5)	641	25	3.1	--

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Table 6-10.
(c) Reported previously in Table 6-8.

-- = No toxicity value exceeded.

significant impacts on the entire populations of these species. However, impacts at J-Field could contribute to cumulative impacts associated with APG.

6.4.4.2 Potential Impacts in Terrestrial Wildlife

Dietary exposures were evaluated for spotted sandpipers feeding along the J-Field shoreline. Table 6-13 presents a comparison of selected toxicity values with estimated exposures for this species. Estimated exposures to lead and mercury in sandpipers feeding on aquatic invertebrates along the J-Field shoreline are below the toxicity values derived for sandpipers.

This comparison suggests that spotted sandpipers and other shore birds feeding on benthic organisms and aquatic insects are not likely to be impacted if the calculated concentrations in surface water are accurate representations of actual conditions. The currently available data are too limited to reach a definitive conclusion regarding the potential for adverse impacts.

6.5 UNCERTAINTIES

As in any risk assessment, there is a large degree of uncertainty associated with the estimates of human health and ecological risks for the J-Field study area. Consequently, estimates cannot be regarded as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the potential risks and to placing the potential risks in proper perspective. The principal sources of uncertainty associated with the APG risk assessments were discussed in general in Chapter 4. For the J-Field study area, the many uncertainties introduced by the incomplete data set are the most limiting factors in the accuracy and completeness of this risk assessment. Some of the key sources of uncertainty associated with the estimates.of risk are summarized below.

6.5.1 UNCERTAINTIES RELATED TO SELECTION OF CHEMICALS FOR EVALUATION

Because of sampling limitations, there is uncertainty regarding the true nature and extent of groundwater and surface water contamination at J-Field. For example, only one round of groundwater and surface water samples was collected. Because of the probable complex interactions between groundwater and surface water at J-Field, (e.g., diurnal and seasonal variations), it is not possible to accurately characterize the extent of contamination without more data.

The limited set of analyses requested for surface water lends additional uncertainty regarding the nature and extent of contamination in the Gunpowder River and the Chesapeake Bay. None of the military compounds that were detected in groundwater (e.g., RDX, thiodiglycol, 1,4-dithiane) were analyzed for. Because groundwater probably discharges to the Gunpowder River and/or the Chesapeake Bay (at least seasonally), chemical contamination in addition to that looked for is possible in surface water, increasing the potential for adverse impacts on aquatic or terrestrial wildlife. Furthermore, it is possible that contamination associated with J-Field extends beyond the immediate shoreline. Samples were not collected from areas further out into the Gunpowder River and Chesapeake Bay, however, so the true extent of contamination and potential exposures is unknown.

TABLE 6-13

COMPARISON OF TOXICITY VALUES WITH ESTIMATED DOSAGES FOR SPOTTED SANDPIPER EXPOSED TO CHEMICALS THAT HAVE ACCUMULATED IN AQUATIC INVERTEBRATES AT J-FIELD

Chemical (a)	Toxicity Value (b) (mg/kg bw)	Estimated Dosage (c) (mg/kg bw)	Toxicity Value Exceeded?
Lead (PB)	1.2	0.71	No
Mercury (HG)	0.41	0.38	No

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Table 6-11.
(c) Reported previously in Table 6-9.

Lack of sediment data also contributes to uncertainty regarding the potential aquatic life impacts. It is possible that sediment in the marsh next to the toxic pits and in the river and bay adjacent to J-Field is contaminated. Wastes from the toxic pits were pushed into the marsh, and the Gunpowder River, at one point, received direct drainage from the riot control and white phosphorous pits.

Because no site-specific background data were available for surface water, the site-relatedness of inorganic chemicals in these media was determined by comparing site-related chemical concentrations with background data collected from areas near APG. The degree to which these background data are representative of the Gunpowder River near J-Field is probably limited. As a result, chemicals unrelated to the site may have been selected for evaluation.

Limited surface and subsurface soil samples are available. Consequently, potential impacts associated with exposures in these media could not be evaluated.

6.5.2 UNCERTAINTIES ASSOCIATED WITH THE MODELS AND ASSUMPTIONS USED TO ESTIMATE EXPOSURES

The lack of adequate data prevented quantitative evaluate of potential risks to both human and ecological receptors via some pathways. The estimates of exposure point concentrations in the ecological risk assessment were based on very limited data.

There is also uncertainty associated with the estimates of bioconcentration in aquatic life. These estimates were based on a simple partitioning model that assumed equilibrium conditions between the aquatic organism and surface water. The approach also assumed that bioaccumulation in species living along the J-Field shoreline was similar to that reported in the literature for other species. The extent to which either of these assumptions is true affects the accuracy of the exposure estimates.

The assumptions used to estimate intake in sandpipers also contributes uncertainty to the estimates of exposure and impact. Generally conservative assumptions were used when estimating exposures, potentially resulting in overestimates of actual exposures at J-Field.

6.5.3 UNCERTAINTIES IN THE TOXICITY ASSESSMENT

There is a great deal of uncertainty associated with the estimates of toxicity in terrestrial and aquatic wildlife in this assessment. For example, few data were available on toxicity in wild bird species; data used to derive the toxicity values for this assessment are from species not closely related to the sandpiper. In these instances, toxicity values were estimated by applying uncertainty factors (divisors) to the data.

6.6 PRINCIPAL DATA NEEDS

Investigations to date have not provided a complete and exhaustive characterization of the type and extent of contamination at J-Field. As a result, additional investigation is needed to assess more definitively existing or potential impacts associated with the J-Field study area. The principal requirement for an adequate evaluation of impacts at J-Field is a more complete database on the nature and extent of contamination in all media. Information on aquatic and terrestrial wildlife exposures and/or impacts are also needed. Specific data requirements are summarized below.

Data on the Nature and Extent of Contamination

- Surface and subsurface soil samples should be collected so potential impacts to terrestrial wildlife receptors can be evaluated.

- Additional studies on the groundwater flow beneath J-Field should be conducted to locate the points of groundwater discharge and to define diurnal and seasonal variations in this discharge. Efforts should be made to identify and collect surface water and sediment samples at or near discharge points.

- Sediment samples and additional surface water samples should be collected from the Gunpowder River, the nearby Chesapeake Bay, and the wetland and marsh areas in J-Field. Samples from the river and bay should be collected both near and far from the shoreline to characterize the extent of contamination in these waters. Samples from the marsh should be collected from all areas potentially impacted by groundwater discharge or by direct past waste disposal. Ideally, the samples should be collected at varying times to characterize daily and seasonal changes in surface water contamination that may result from variations in groundwater discharge, tidal effects, dilution, and volatilization. Samples of sediment pore water in the groundwater discharge zone could be used to provide an indication of potential maximum exposure concentrations for benthic species.

- Background surface water and sediment samples are needed to permit a more accurate assessment of the site-relatedness of inorganic chemicals in the Gunpowder River and nearby Chesapeake Bay. Background samples for the Gunpowder River should be collected upstream of J-Field. A sufficient number of samples should be collected to permit statistical evaluation.

- Samples from all media should be analyzed for the range of military-unique and other compounds potentially present at J-Field. Surface water sample analysis should include cyanide.

Data Related to Wildlife Exposures and/or Impacts

- Invertebrates living along the J-Field shoreline and in the marsh (particularly near the toxic pits) should be collected for whole-body residue analysis. Efforts should be made to collect year-round and seasonal populations of invertebrates (i.e., aquatic insect larvae). Analytes should include at a minimum all priority pollutant metals and ideally should include a range of organic chemicals that are potentially present at J-Field and may accumulate in aquatic organisms.

- If additional surface water sampling and sediment sampling indicate widespread contamination in the Gunpowder River and Chesapeake Bay off of J-Field, more extensive tissue sampling involving predatory and bottom feeding fish may be warranted.

- Benthic macroinvertebrate species surveys are needed to provide some indication of the nature of impacts (if any) to sediment-dwelling species along the J-Field shoreline and in the marsh. Studies should include benthic species samples from a suitable background location.

If additional media sampling suggest that aquatic life may be impacted significantly by exposure to chemicals in surface water and sediment, the following additional tests may be warranted.

- Sediment toxicity tests could be conducted to assess the impacts associated with chemicals sorbed onto sediments. Suitable laboratory and field controls are needed.
- Aquatic toxicity tests could be conducted to assess the toxicity of surface water contaminants. Tests should include acute toxicity tests and chronic or early-life-stage tests with invertebrates and fish.

6.7 SUMMARY AND CONCLUSIONS

This baseline risk assessment addressed potential impacts on human health and the environment associated with the J-Field study area in the absence of remedial actions. The field investigation conducted by USGS in 1988 and 1990 was the primary source of sampling data considered in this assessment. Sampling data were available only for groundwater and surface water. Chemical analyses were limited primarily to volatile, semivolatile, and inorganic chemicals, although selected groundwater samples were analyzed for agent- and explosive-related compounds, herbicides, and radionuclides. Based on the limited sampling data, inorganic chemicals (i.e., metals) and volatile organic chemicals are the primary chemicals of concern in groundwater and surface water. Agent degradation products and explosive-related compounds also are of concern in groundwater (the only medium sampled for these compounds).

6.7.1 HUMAN HEALTH RISK ASSESSMENT SUMMARY

The primary pathways by which human populations could be exposed to chemicals of potential concern under current land-use conditions is inhalation by workers of chemicals on windblown dust or volatilized from surface water or subsurface groundwater, soil, or wastes. No other potential pathways are likely to result in significant exposure under current land-use conditions. The only human exposure pathway potentially complete under future land-use conditions is dermal contact and incidental ingestion of chemicals in surface water by persons swimming in the Gunpowder River. Exposure pathways under both current and future land-use conditions were evaluated qualitatively in this assessment.

The estimated human health risks associated with these pathways are as follows:

Current Land-Use

- Workers at J-Field are unlikely to experience significant risks as a result of inhalation of chemicals that are present on dust or that have volatilized from surface water or the subsurface environment (e.g., subsurface soil, wastes, or groundwater) given the infrequency and limited duration of human activities at J-Field. However, significant risks could be possible if chemical emissions are high.

Future Land-Use

- Based on the current sampling data, persons swimming in the Gunpowder River near J-Field are unlikely to experience significant health risks because the concentrations of chemicals present in surface water are low compared to toxic concentrations.

6.7.2 ECOLOGICAL ASSESSMENT SUMMARY

Potential ecological impacts were evaluated for aquatic and terrestrial wildlife at J-Field. Aquatic life exposures were evaluated for chemicals in surface water in the Gunpowder River and Chesapeake Bay along the J-Field shoreline. Terrestrial wildlife exposures were evaluated for sandpipers (an aquatic insectivore) feeding in surface water near J-Field and exposed to chemicals that have accumulated in food. The results of the assessment are as follows:

Aquatic Life Impacts

- Preliminary findings suggest that chemical contaminants in surface water could be impacting aquatic life along the J-Field shoreline. Additional sampling data are needed before a more definitive conclusion can be made. The more static nature of waters in the extensive wetlands and marshes compared to the Gunpowder River and Chesapeake Bay may make organisms inhabiting them more susceptible to impacts than those in the river and bay if groundwater is discharging to the marsh; at the present time, however, chemical concentrations in the wetlands are unknown.

Terrestrial Wildlife

- Preliminary findings indicate that shorebirds feeding in the surface water near J-Field are unlikely to be adversely impacted by exposure to heavy metals in their food. Additional sampling data are needed before a more definitive conclusion can be made.

6.7.3 CONCLUSIONS OF THE RISK ASSESSMENT

Past activities at J-Field may have resulted in significant contamination of soil, groundwater, surface water, and sediment in the area. Few data are available on chemical concentrations in these media, but widespread contamination is likely. Under current-land use conditions, ecological populations are the principal receptors of concern. Few human health exposure pathways exist under current land-use conditions, and data are inadequate to assess the potential for increased health risks. Human use of J-Field is unlikely to change in the future. Persons swimming off the J-Field shoreline under future-use conditions are unlikely to be at increased health risk.

It is possible that the aquatic organisms in the Gunpowder River and the nearby Chesapeake Bay are being adversely affected by chemical contamination associated with J-Field. Because the J-Field area supports only a small percentage of the entire aquatic community of APG, impacts there are unlikely to have significant impacts on the aquatic populations at APG or in the northern Chesapeake Bay. However, if impacts are occurring at J-Field, they could result in localized reductions in population size and could contribute to cumulative impacts associated with APG as a whole.

Shorebirds feeding in the Gunpowder River do not appear to be at risk from exposure to heavy metals in the diet. However, chemicals not analyzed for in surface water and chemicals present in surface soil at J-Field could be present at levels that are impacting wildlife. .

These risk estimates risk are preliminary. There is a great deal of uncertainty associated with all risk estimates for the J-Field study area, because of limitations associated with the available sampling data, as well as the limitations inherent to the risk assessment process. Additional investigation is needed to assess more definitively existing or potential impacts associated witn the J-Field study area.

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7.0 CANAL CREEK RISK ASSESSMENT

This chapter evaluates potential impacts on human health and the environment associated with the Canal Creek study area in the absence of additional remedial (corrective) actions. The hydrogeologic, surface water, and soil studies conducted by USGS from 1986 to 1989 are the primary sources of sampling data considered in this risk assessment. Data from this study were obtained from the following sources: (1) published study reports (USGS 1989a); (2) letter reports containing hard copies of summarized chemical data (USGS 1989b, 1990a); (3) hard copies of recent data received directly from USGS (USGS 1990b); and (4) data contained in the USATHAMA database (IRDMS). Sediment data used in this risk assessment were obtained from AEHA (1985, 1987) because sediment samples were not collected as part of the USGS study. The USGS and AEHA data were used in this risk assessment because together they comprise the most recent and comprehensive data base available for the Canal Creek study area. Data from other studies conducted at Canal Creek are briefly discussed where applicable to support evaluations of potential exposures or risks.

These and other investigations conducted to date have not completely characterized the nature and extent of contamination at the Canal Creek study area. Therefore, this risk assessment should be considered largely preliminary and is intended as an initial step in the overall risk assessment process for the Canal Creek study area.

This assessment follows the general risk assessment methodology outlined in Chapter 4 of this report, which should be consulted for the rationale and further details of the methods used in this assessment. This assessment is organized into eight primary sections:

- Section 7.1 Background Information
- Section 7.2 Selection of Chemicals of Potential Concern
- Section 7.3 Human Health Risk Assessment
- Section 7.4 Ecological Assessment
- Section 7.5 Uncertainties
- Section 7.6 Principal Data Gaps
- Section 7.7 Summary and Conclusions
- Section 7.8 References

7.1 BACKGROUND INFORMATION[1]

The Canal Creek study area is a large industrial sector of APG that has supported the majority of APG's former chemical agent, smoke/incendiary, and protective-clothing manufacturing operations. The Canal Creek study area is located in the northern section of the Edgewood Area adjacent to the northern end of the Gunpowder Neck. For the purposes of this report, the Canal Creek study area has been defined as the watershed bordered to the north by the Penn Central railroad tracks, to the south/southwest by the Gunpowder River, to the south/southeast by a security fence that prevents access to the Gunpowder Neck, to the east by Ricketts Point Road, and to the west by some lands just west of the wetlands area of the West Branch of Canal Creek. Figure 7-1 shows the Canal Creek study area and its boundaries. The area between the East and West Branches of Canal Creek is where most of the former manufacturing and filling plants were concentrated.

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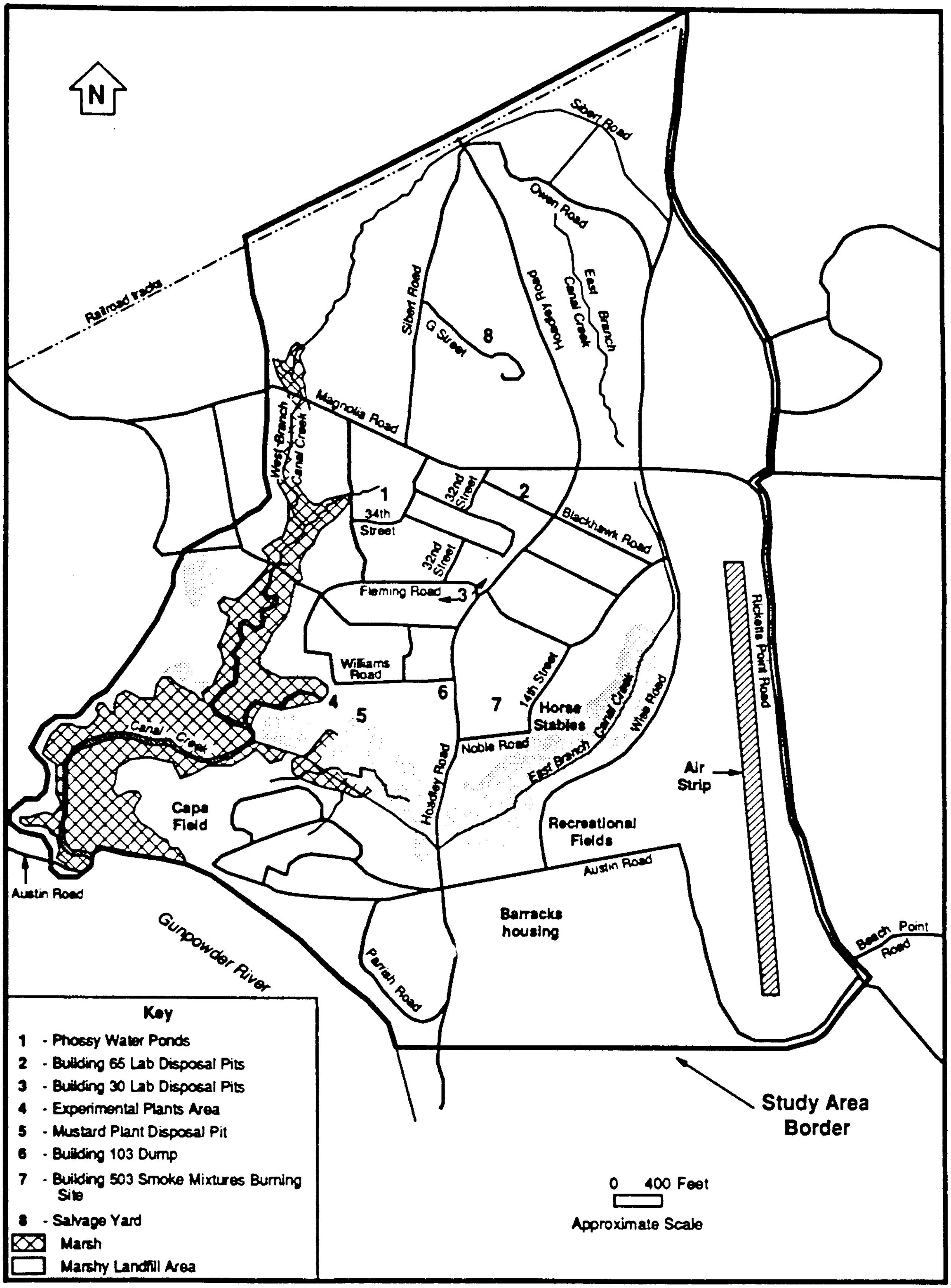
[1] Information in this section is summarized primarily from AEHA (1989).

Figure 7-1
Canal Creek Study Area



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Most of the land in this study area is developed. However, there are forested areas in the northern and western portions of the study area and wetlands along most of Canal Creek and parts of the Gunpowder River shoreline, near the mouth of Canal Creek.

The Canal Creek study area has been an important chemical warfare research and development center for the United States since 1917. Research and development activities in the Canal Creek area have included laboratory research, field testing, and pilot-scale and full-scale manufacturing of chemical materials. Specific operations included:

- White phosphorus munitions loading and filling;
- Pyrotechnic blending and loading;
- Protective clothing manufacturing and impregnation;
- Pilot plant operations for nerve agent and mustard production, munitions filling and demilitarization;
- Production of activated carbon filters;
- Production of thermite bombs; and
- Studies utilizing nitrogen and hydrazine derivatives.

Other activities at Canal Creek included operation of machine and maintenance shop garages, fabrication of metal parts, degreasing, and metal plating.

A variety of chemical products and agents were used or produced in the Canal Creek study area. Some of the primary chemical products manufactured or used at the Canal Creek area were: chlorine (used as a raw material and in many chemical agents); mustard; chloroacetophenone (CN); phosgene (CG); CC2 (a clothing-impregnating material); chloropicrin; white phosphorus (WP); and pyrotechnical arsenicals (i.e., lewisite, adamsite [DM], diphenylchloroarsine [DA], methyldichloroarsine).

Portions of the Canal Creek area also were used for landfilling of sanitary wastes and for the disposal of production wastes. The primary method of liquid waste disposal from 1917 until the late 1970s was discharge of untreated liquid wastes through sewer lines into the East and West Branches of Canal Creek. Disposal of solid wastes often consisted of dumping the wastes in wetland areas along the creek, or in pits or dumps next to laboratory buildings or pilot plants. In addition to disposing of wastes in the main disposal pits, it was common near certain laboratory areas to dig a small hole, dump the contents of a test tube in the hole, and cover it up.

Table 7-1 provides a list of many of the chemicals believed to have been manufactured, used, or disposed of in the Canal Creek study area.

Due to these past waste disposal practices, the Canal Creek area contains many potential contamination source areas. These are concentrated primarily between the East and West Branches of Canal Creek, where many of the laboratory, manufacturing and production operations took place. The source areas evaluated in this assessment are primarily waste disposal pits associated with laboratories or pilot plants. The nine source areas that are the focus of this assessment are shown in Figure 7-1 and described below.

TABLE 7-1

PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT CANAL CREEK (a)

Group	Chemical Compound (Acronym) (b)
Lethal Chemical Agents	+ Mustards (H, HD)
	+ Lewisite (L)
	M-1, M-2, M-3 [used in Lewisite production]
	+ Phosgene (CG)
	+ Bromobenzylcyanide (BBC)
	+ Tabun (GA)
	+ Soman (GD)
Incapacitating Agents	+ Chloropicrin (PS)
	+ Chloroacetophenone (CN)
	Diphenylchloroarsine (DA)
	Diphenylcyanoarsine (CDA)
	+ Adamsite (DM)
	DM Oxide
	O-Chlorobenzylidene Malononitrile (CS)
	3 Quinuclidinyl Benzilate (BZ)
	CNB
	CNS
Solvents	+ Hexachloroethane (HCA) [major component of HC smoke]
	+ 1,1,2,2-Tetrachloroethane [major component of DANC]
	1,2-Dichloroethane
	+ Chlorinated Ethenes and Ethanes
	Ethylene Chlorohydrin
	+ Tetrachloroethene
	trans-1,2-Dichloroethene
	Trichloroethene
	+ Carbon Tetrachloride
	+ Chloroform
	+ Benzene
	+ Chlorobenzene
	+ Acetone
	+ Xylene
	+ Hexachlorobenzene
	+ Hexachlorobutadiene
Decontaminating Agents	Decontaminating Agent - Noncorrosive (DANC)
	+ Super Tropical Bleach (STB)
Organic Sulfur Compounds	Thiodyglycol
	+ Nitrogen Mustard/Sulfur Sludge
Metals/Inorganics	+ Various Metals/Inorganic Compounds
	Metal Salts
	+ Arsenical Compounds
Smoke/Incendiary Materials	+ HC Smoke Mixtures [Types (A and B), (C)]
	+ White Phosphorus (WP)
	Phosphorus
	Sulfur Trioxide and Chlorosulfonic Acid Mixture (FS)
Munitions Compounds	+ Some unexploded ordnance
CC2 and CC3 Impregnating Materials	+ Various CC2 compounds
	2,4,6-Trichloroanaline
	+ TCPU
	+ Sym-diphenylurea (DPU)
	+ Whetlerite
Dyes	B-1 dye
	+ 1-Methylaminoanthraquinone
	+ 1,2-Di-p-toluidinoanthraquinone
	+ Dibenzo(b,def)chrysene-7,14-dione
	+ 1,4-Diamino-2,3-dihydroanthraquinone
	+ 7H-Benz(de)anthracene-7-one

See footnotes on the following page.

TABLE 7-1 (Continued)

PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT CANAL CREEK (a)

Group	Chemical Compound (Acronym) (b)
Oils/Fuels	Kerosene, chlorinated kerosene Heat transfer oil
Miscellaneous Compounds/ Wastes	Contaminated equipment Cellulose nitrates + PCBs HCl Diphenylamine Alcohol Polyvinyl alcohol Formaldehyde Paraformaldehyde Asbestos Methyldichloro-phosphine (SW) [used in VX production] + Incinerator ash

(a) Information obtained primarily from AEHA (1989).
(b) See Glossary of Acronyms and Abbreviations for complete chemical name if not given in this table.

+ = These chemicals are known to have been disposed of in the source areas of Canal Creek.

Building 103 Dump. Past activities at this dump included disposal of storage tanks containing mustard and sulfur sludge and possibly other chemicals, equipment, and some ordnance. Burning of some of these materials occurred in the dump. It is not known if these tanks were later removed. The contents of a tank that was protruding from the pit were sampled and were found to be a mixture of organic chemicals, with the greatest portion being bromobenzylcyanide.

Building 30 Lab Disposal Pits. This area consists of at least three disposal pits and possibly others. Laboratory wastes that were disposed in these pits included chlorinated solvents, mustard, nitrogen mustards, lewisite, chlorpicrin, chemically contaminated items (such as laboratory equipment) and explosive items. Arsenical compounds also were probably disposed in these pits given the type of research done in these laboratories.

Building 65 Lab Disposal Pits. This area consists of one main pit, and possibly other smaller pits. Laboratory wastes that were disposed of in these pits are similar to those disposed of in the Building 30 pits described above.

Building 503 Smoke Mixture Burning Sites. Experimental smoke mixtures and smoke munitions were burned in this area, either for testing or for disposal purposes. Batches of HC (containing hexachloroethane) smoke that did not meet specifications (off-spec batches) were burned in bulk. The principal constituents of HC smoke are hexachloroethane and zinc oxide; other possible constituents include grained aluminum, ammonium chloride, ammonium, and potassium perchlorate. Colored smoke mixtures containing dyes also were burned in this area. The dyes used in these smoke mixtures included: 1-methylaminoanthraquinone; 1,2-di-p-toluidinoanthraquinone; dibenzo(b,def)chrysene-7,14-dione; 1,4-diamino-2,3-dihydroanthraquinone; 7H-benz(de)anthracene-7-one. Smoke munitions burned in this area contained starter mixes of silicon, potassium nitrate, charcoal, iron oxide, grained aluminum, cellulose nitrates, and acetone.

Mustard Plant Disposal Pit. This pit was constructed primarily to receive off-specification batches of mustard, which were released directly to the Canal Creek marsh before the pit was constructed. The pit also was used to dispose of mustard manufacturing waste. During the time the pit was in use, waste water drainage/runoff from the pit westward into the marsh was observed.

Phossy Water Ponds. Two unlined wastewater storage ponds received wastewater generated by white phosphorus and plasticized white phosphorus (PWP) filling operations. Wastewaters were oxidized before being released to the ponds to remove most of the white phosphorus. As a result of this treatment process, wastewaters containing dissolved and suspended phosphates and dissolved xylene were generated.

Marshy Landfill Area. The Canal Creek marsh has been used as a dumping, burial, landfill, and discharge area from 1917 until recent times. The original wetlands area was much larger than it is now, especially along the East Branch of Canal Creek, where landfilling eliminated most of the marsh area. Backfilling and landfilling of wetlands also occurred along the West Branch. Landfilling occurred from less than 5 feet above mean sea level to about 15 feet above mean sea level in fill areas along the East Branch. The thickness of the cover of the landfill probably has a maximum of 1-2 feet in most areas.

Experimental Plants Area. Many experimental pilot plants were operated in the Canal Creek study area. Operations included experimental mustard production, mustard distillation, clothing impregnating, lewisite production, and filling of white phosphorus munitions and adamsite and o-chlorobenzylidene malononitrile [CS] grenades. Ton containers holding mustard and possibly other chemical agents were decontaminated in this area. Mustard-containing sludge was discharged into a pit, which is now closed. It is unknown if the contents of the pit were removed prior to closure.

Salvage Yard. The Salvage Yard was used primarily as a handling and processing area for salvageable items, including chemicals (e.g., solvents). This area also was used as a fire training area.

7.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

In this section, environmental monitoring data to be used in this risk assessment are briefly summarized, and the chemicals of potential concern selected for further evaluation are identified. Sampling data were available for surface soil, groundwater, surface water, and sediment. The discussions are organized below by environmental medium.

7.2.1 SURFACE SOIL

USGS collected surface soil samples (2-inch depth) from 45 locations in the Canal Creek study area, primarily from the area between the East and West Branches of Canal Creek. One background sample was collected from an area northwest of the Salvage Yard and west of Sibert Road. Samples were analyzed for volatile and semivolatile organic chemicals, pesticides, PCBs, inorganic chemicals, 2,4-dinitrotoluene, and 2,6-dinitrotoluene. The results of these analyses are presented in Table 7-2. These data have been summarized from data contained in IRMDS.

Four classes of organic chemicals were detected in the surface soil samples. These classes are chlorinated pesticides (DDE), phthalates (di-n-butylphthalate), PAHs (numerous compounds), and freons (1,1,2-trichloro-1,2,2-trifluoroethane, and trichlorofluoromethane). No other organic chemicals were detected. However, some of the detection limits for some of the other organic chemicals (principally PCBs and pesticides) were high, possibly masking the actual occurrence of these chemicals in Canal Creek area soils. For example, the detection limits for the PCBs ranged from 1,520 to 3,060 ug/kg, and those for toxaphene ranged from 2,820 to 3,120 ug/kg.

Except for PAHs, all organic chemicals identified in surface soil were selected as chemicals of potential concern. PAHs are ubiquitous components of the environment and occur primarily as a result of incomplete combustion of hydrocarbon fuel and other carbon-containing materials. "Background" levels are generally highest in areas with concentrated combustion sources, such as urban and industrial areas or areas near roadways. A review of the literature on background soil concentrations of PAHs indicates that the concentrations of individual PAHs in urban/industrial soils can range up to 100 mg/kg or higher.[2] The levels of PAHs detected in the Canal Creek surface soils are well below this value and probably are the result of general human activity in the Canal Creek area rather than being associated with any past waste disposal activity. For this reason, PAHs were not selected as chemicals of potential concern for the Canal Creek study area. No PAHs were detected in the single background sample collected by USGS, but that sample was collected from an area of less concentrated human activity, and therefore, may not be appropriate for an evaluation of PAH levels in the more populated areas of the Canal Creek study area.

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[2] See IARC (1973), Blumer et al. (1977), White and Vanderslice (1980), Winsor and Hites (1979), Pucknat (1981), Edwards (1983), Butler et al. (1984), Vogt et al. (1987), and Jones et al. (1989).

TABLE 7-2

SUMMARY OF CHEMICALS DETECTED IN SURFACE SOIL AT CANAL CREEK

(Concentrations reported in ug/kg for organics, and in mg/kg for inorganics)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
Organic Chemicals:			
* p,p'-DDE (PPDDE)	2 / 32	482 - 595	ND
* Di-n-butylphthalate (DNBP)	3 / 32	95.0 - 210	ND
PAHs [carcinogenic]	9 / 32	859 - 3,980	ND
Benzo(a)anthracene (BAANTR)	4 / 32	171 - 542	ND
Benzo(a)pyrene (BAPYR)	2 / 32	496 - 872	ND
Benzo(b)fluoranthene (BBFANT)	3 / 32	368 - 804	ND
Benzo(k)fluoranthene (BKFANT)	9 / 32	83.0 - 444	ND
Chrysene (CHRY)	9 / 32	183 - 829	ND
Indeno(1,2,3-c,d)pyrene (ICDPYR)	1 / 32	487	ND
PAHs [noncarcinogenic]	11 / 32	371 - 3,420	ND
Acenaphthylene (ANAPYL)	1 / 32	217	ND
Anthracene (ANTRC)	3 / 32	65.8 - 253	ND
Benzo(g,h,i)perylene (BGHIPY)	2 / 32	270 - 497	ND
Dibenzofuran (DBZFUR)	1 / 32	141	ND
Fluoranthrene (FANT)	10 / 32	122 - 938	ND
Fluorene (FLRENE)	1 / 32	149	ND
2-Methylnaphthalene (2MNAP)	1 / 32	93.0	ND
Naphthalene (NAP)	1 / 32	189	ND
Phenanthrene (PHANTR)	8 / 32	46.0 - 1,010	ND
Pyrene (PYR)	10 / 32	110 - 707	ND
* 1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	13 / 13	21.0 - 52.0	ND
* Trichlorofluoromethane (CCL3F)	2 / 34	6.5 - 28.0	ND
Inorganic Chemicals:			
* Antimony (SB)	12 / 33	8.1 - 20.7	ND
* Arsenic (AS)	32 / 32	2.4 - 11.0	3.7
Calcium (CA)	33 / 33	220 - 58,000	233
* Chromium (CR)	20 / 33	23.7 - 139	ND
* Copper (CU)	1 / 33	104	ND
* Iron (FE)	33 / 33	1,400 - 54,000	11,000
* Lead (PB)	13 / 13	2.1 - 1,100	ND
Magnesium (MG)	33 / 33	397 - 14,000	1,140
* Manganese (MN)	33 / 33	62.8 - 2,930	205
* Mercury (HG)	14 / 45	0.1 - 0.9	ND
* Selenium (SE)	1 / 45	1.2	ND
Sodium (NA)	33 / 33	239 - 1,620	298
* Zinc (ZN)	21 / 33	62.7 - 361	ND

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 2 - 46.
(d) Sample: 1.

ND = Not detected.
* = Selected as a chemical of potential concern. See text.

The inorganic chemicals detected in surface soil also are presented in Table 7-2. Based on a comparison to chemical concentrations reported for the single background soil sample, all inorganic chemicals in surface soil are considered to be site-related (see Chapter 4 for comparison methodology). Therefore, all inorganic chemicals, except those of relatively low toxicity (calcium, magnesium, and sodium), are selected as chemicals of potential concern.

In addition to the chemicals of potential concern, several other chemicals were tentatively identified in surface soil samples. Table 7-3 summarizes concentration and frequency data for these tentatively identified compounds (TICs). These chemicals are mostly fatty acids, which can be present in a variety of substances such as incendiary materials (napalm), oils, and soaps. The acidic form of 4-methylbenzene sulfonamide is used in dye chemistry. Some of these chemicals (the fatty acids and esters) are naturally occurring; one of the chemicals (vanillin) is used as a flavoring in food. All of these chemicals were detected infrequently and at concentrations between 116 ug/kg and 798 ug/kg. None of these TICs were selected as chemicals of concern.

7.2.2 GROUNDWATER

USGS conducted a four-phase hydrogeologic field investigation from 1986 to 1989. Phase 1 data were obtained from a published study report (USGS 1989a). Phase 2 data were obtained directly from USGS on data summary sheets (USGS 1990b). Phase 3 and 4 data were summarized from IRDMS. No study reports are available that summarize data from phases 2-4.

Groundwater samples were collected from 107 monitoring wells in the Canal Creek study area and from 2 wells located in the northwest portions of the study area, just within the APG boundary. These latter two wells are upgradient of the sources of contamination investigated in this risk assessment, and were considered as background wells. Most of the downgradient monitoring wells (99) were located in the main industrial sector of the Canal Creek study area and eight were located in the northern portions of the study area, near the Salvage Yard area. In this assessment, the Salvage Yard wells were considered separately from the wells located in the main industrial sector of the study area, given that they are located around a distinct source, north of the main industrial area.

Phase 1 groundwater samples were collected from wells located near suspected areas of contamination in the industrial section of Canal Creek and in the salvage yard area. Phase 2, 3, and 4 groundwater samples were collected from phase 1 wells and from additional wells installed during phase 2 in areas that had shown elevated chemical concentrations in Phase 1.

All groundwater samples were analyzed for inorganic chemicals and for organic chemicals routinely analyzed by EPA methods 624 (volatile organics) and 625 (base/neutral and acid extractables). Data on chemical concentrations in blanks were available for phase 1 and 2 data. Phase 1 sample data were reported in USGS (1989a) with laboratory blank concentrations subtracted from the concentrations in site-related samples. For Phase 2 data, chemical concentrations in site-related samples were compared to those reported in blanks using the methodology outlined in Chapter 4. Chemicals determined to be blank contaminants using this methodology were not included in this risk assessment.

The results of the USGS groundwater investigation are discussed separately below for the main industrial sector of the Canal Creek area and the Salvage Yard area.

TABLE 7-3

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN SURFACE SOIL AT CANAL CREEK

(Concentrations reported in ug/kg)

Chemical (a)	Number of Detects (b)	Range of Reported Concentrations (c)
Cyclohexene Oxide/1,2-Epoxy-cyclohexene (12EPCH)	3	222 - 226
Hexadecanoic Acid/Palmitic Acid (C16A)	1	116
Hexadecanoic Acid, Butyl Ester (C16ABE)	2	225 - 350
4-Hydroxy-3-Methoxybenzaldehyde/Vanillin (4H3MBA)	1	233
4-Methylbenzene Sulfonamide (4MBSA)	1	798
Octadecanoic Acid, Butyl Ester (C18ABE)	3	220 - 338

(a) USATHAMA chemical codes listed in parentheses.
(b) Number of samples in which the chemical was tentatively identified.
(c) Samples: 2 - 46.

7.2.2.1 Main Industrial Section of Canal Creek Study Area

Groundwater samples were collected from the three uppermost aquifers in the main industrial section of the Canal Creek study area: the surficial aquifer, the Canal Creek aquifer, and the lower confined aquifer. Because the surficial aquifer and the Canal Creek aquifer are hydraulically connected near the West Branch of Canal Creek and in the paleochannel near the East Branch of Canal Creek, they were treated in this assessment as a single unit. The lower confined aquifer was considered separately from the two uppermost aquifers because it is separated completely from them by an overlying confining unit (USGS 1989c). Eighty-nine wells were sampled in the surficial and Canal Creek aquifers in the main industrial section of the Canal Creek study area. Ten wells were sampled from the lower confined aquifer.

The two background groundwater samples were collected from the lower confined aquifer. It was not possible to obtain background samples for the surficial and Canal Creek aquifers because these aquifers crop out in the West Branch of Canal Creek. As a result, there is no upgradient, uncontaminated portion of these aquifers that would be considered appropriate as locations for background wells. In the absence of more appropriate data, therefore, the background data from the lower confined aquifer were used in this assessment to represent background conditions for the surficial and Canal Creek aquifers, as well as the lower confined aquifer. Concentrations of inorganic chemicals in groundwater samples were compared to these background concentrations to determine if the chemical was present in the sample at naturally occurring levels (see Chapter 4 for comparison methodology). It is recognized that differences in mineralogy and lithology between the aquifers could result in considerable differences in the "background" for each aquifer. Nevertheless, it was considered more appropriate to use site-related background concentrations rather than a non-site-specific set of background concentrations.

Data for the Canal Creek and surficial aquifers and the lower confined aquifers are discussed separately below.

7.2.2.1.1 Canal Creek Aquifer and Surficial Aquifer

Table 7-4 presents the frequency of detection and range of concentrations for the chemicals detected in the surficial and Canal Creek aquifers, along with information on chemical concentrations in the background wells. Because of the large number of chemicals detected, the data have been grouped into chemical classes to facilitate an understanding of the types of contamination present in these aquifers. These organic chemical classes are alkyl aromatics (benzene, m-xylene, ethyl benzene, and toluene); halogenated aromatics (4-bromofluorobenzene, chlorobenzene, and various di- and trichlorobenzenes); cyclic sulfur compounds (dithiane and 1,4-oxathiane); ethers (bis[2-chloroethyl]ether); halogenated alkanes (various chlorinated methanes and ethanes); halogenated alkenes (various chlorinated ethenes and propenes); ketones (acetone and methyl ethyl ketone); nitroaromatics (nitrobenzene); and phthalates (butylbenzylphthalate, bis[2-ethylhexyl]phthalate). Of these chemical classes, halogenated alkanes and alkenes are present to the greatest extent and at the highest overall concentrations.

Because of the relatively large number of chemicals detected, a subset of the chemicals in these classes was selected for evaluation in this risk assessment according to frequency of detection and concentration (see Chapter 4). Organic chemicals that were detected in up to approximately 10% of the samples and at low concentrations (<50 µg/L) were eliminated from the group of chemicals of

TABLE 7-4

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
ORGANIC CHEMICALS:			
Alkyl aromatics:			
* Benzene (C6H6)	20 / 87	1.0 - 92.0	ND
1,3-Dimethylbenzene / M-Xylene (13DMB)	1 / 54	2.3	ND
* Ethyl Benzene (ETC6H5)	39 / 87	0.9 - 5.8	ND
Toluene (MEC6H5)	14 / 87	1.5 - 5.0	ND
Halogenated aromatics:			
* 4-Bromofluorobenzene (4BFB)	18 / 18	22.0 - 160	ND
* Chlorobenzene (CLC6H5)	19 / 87	0.7 - 50.4	ND
1,2-Dichlorobenzene (12DCLB)	3 / 54	12.3 - 23.0	ND
1,3-Dichlorobenzene (13DCLB)	5 / 54	0.4 - 1.2	ND
1,4-Dichlorobenzene (14DCLB)	2 / 54	3.3 - 21.3	ND
1,2,3-Trichlorobenzene (123TCB)	1 / 17	13.6	ND
1,2,4-Trichlorobenzene (124TCB)	1 / 17	4.2	ND
Cyclic sulfur compounds:			
* Dithiane (DITH)	1 / 17	7.0	ND
* 1,4-Oxathiane (OXAT)	1 / 17	19.8	ND
Ethers:			
* bis(2-Chloroethyl)ether (B2CLEE)	1 / 17	7.1	ND
Halogenated alkanes:			
* Carbon Tetrachloride (CCL4)	40 / 87	1.6 - 8,370	ND
Chloroethane (C2H5CL)	1 / 54	0.9	ND
* Chloroform (CHCL3)	56 / 87	1.0 - 565	ND
Chloromethane (CH3CL)	3 / 54	0.8 - 2.1	ND
1,1-Dichloroethane (11DCLE)	9 / 87	1.0 - 5.0	ND
* 1,2-Dichloroethane (12DCLE)	29 / 87	1.4 - 283	ND
1,2-Dichloropropane (12DCLP)	3 / 54	0.1 - 0.5	ND
* Methylene Chloride (CH2CL2)	67 / 82	0.8 - 50.4	4.8 - 8.0
* 1,1,2,2-Tetrachloroethane (TCLEA)	63 / 87	1.4 - 4,030	ND
1,1,1-Trichloroethane (111TCE)	2 / 54	0.2 - 1.3	ND
* 1,1,2-Trichloroethane (112TCE)	32 / 87	1.4 - 31.1	ND
Halogenated alkenes:			
1,1-Dichloroethene (11DCE)	13 / 87	1.0 - 13.0	ND
1,2-Dichloroethene [total] (12DCE)	29 / 54	1.2 - 168	ND
* cis-1,2-Dichloroethene (C12DCE)	13 / 13	2.0 - 2,500	ND
* trans-1,2-Dichloroethene (T12DCE)	47 / 87	0.9 - 1,090	ND
1,3-Dichloropropene (13DCP)	1 / 54	5.3	ND
* Tetrachloroethene (TCLEE)	39 / 87	0.9 - 110	ND
* Trichloroethene (TRCLE)	65 / 87	1.9 - 537	ND
* Vinyl Chloride (C2H3CL)	20 / 87	1.6 - 139	ND
Ketones:			
Acetone (ACET)	1 / 54	5.7	ND
Methylethyl Ketone (MEK)	1 / 54	12.0	ND
Nitro aromatics:			
* Nitrobenzene (NB)	2 / 17	89.5 - 111	ND
Phthalates:			
* Butylbenzylphthalate (BBZP)	3 / 17	10.0 - 100	ND
* bis(2-Ethylhexyl)phthalate (B2EHP)	10 / 30	10.0 - 30.0	ND

See footnotes on the following page.

TABLE 7-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
INORGANIC CHEMICALS:			
* Aluminum (AL)	41 / 54	130 - 21,500	ND
* Ammonia (NH3)	38 / 86	110 - 5,600	ND
* Ammonia+Organic Nitrogen	81 / 86	105 - 6,150	440 - 500
* Antimony (SB)	18 / 77	3.0 - 12.0	ND
* Arsenic (AS)	25 / 87	1.6 - 45.0	ND
* Barium (BA)	54 / 54	6.8 - 278	ND
Beryllium (BE)	4 / 87	2.0 - 19.0	ND
* Boron (B)	68 / 87	10.0 - 1,480	30.0 - 50.0
Bromide (BR)	52 / 70	40.5 - 911	ND
* Cadmium (CD)	53 / 87	1.0 - 17.0	6.0
Calcium (CA)	87 / 87	1,170 - 395,000	1,200 - 1,900
Chloride (CL)	85 / 87	2,100 - 1,040,000	4,800 - 12,000
* Chromium (CR)	45 / 87	1.0 - 20.1	ND
* Copper (CU)	59 / 87	1.0 - 169	1.0 - 17.0
* Fluoride (F)	73 / 87	57.0 - 4,480	ND
* Iron (FE)	86 / 87	12.0 - 51,000	330 - 520
* Lead (PB)	26 / 54	3.5 - 65.5	ND
Magnesium (MG)	87 / 87	45.0 - 27,600	550 - 890
* Manganese (MN)	85 / 87	2.0 - 24,500	40.0 - 80.0
* Mercury (HG)	29 / 87	0.3 - 1.2	ND
* Nickel (NI)	70 / 87	2.0 - 214	17.0 - 27.0
* Nitrite (NO2)	58 / 87	7.5 - 170	ND
* Nitrite/Nitrate (NIT) (e)	85 / 87	22.5 - 3,200	100 - 360
Phosphorus (P4)	56 / 86	7.5 - 113	ND
Potassium (K)	87 / 87	638 - 102,000	1,200
Selenium (SE)	11 / 87	1.0 - 3.0	ND
Silver (AG)	8 / 52	0.3 - 1.2	ND
Sodium (NA)	87 / 87	3,200 - 503,300	2,900 - 10,000
* Sulfate (SO4)	82 / 87	927 - 183,000	4,000 - 8,000
* Sulfide (SULFID)	8 / 31	1,100 - 3,400	ND
Thallium (TL)	1 / 54	36.6	ND
* Zinc (ZN)	85 / 87	4.0 - 3,390	28.0 - 73.0

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 1 (A,B,C); 2A; 4 (A,B); 5 (B,C); 7 (A, A.1, B); 13 (A,B); 14 (A,B); 15A; 16 (A,B); 17 (A,B); 18 (A,B); 19 (A,B); 20 (A,B,C,D); 21A; 22 (A,B,C); 23 (A,B); 25 (A,B); 26 (A,B); 27 (A,B); 28 (A,B); 29 (A,B); 30A; 31A; 36 (A,B,C,D); 44A; 101 (A,B,C); 106A; 107 (A,B); 108 (A,B); 109 (A,B); 110A; 111 (A,B); 112A; 113 (A,B); 114 (A,B,C); 115A; 118 (A,B); 120A; 122A; 123 (A,B); 124 (A,B); 130 (A,B); 133 (A,B); 134 (A,B); W6.
(d) Samples: 139A and 140A.
(e) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

ND = Not detected.
* = Selected as a chemical of potential concern. See text.

potential concern. The remaining organic chemicals were selected as chemicals of potential concern. These are designated in Table 7-4.

Of the remaining organic chemicals, the halogenated alkanes and alkenes were detected most frequently at the highest concentrations. Halogenated alkanes and alkenes undergo transformations to lesser chlorinated species under low oxygen conditions in the subsurface as a result of microbial action. An examination of the chemicals measured in the Canal Creek and the surficial aquifers indicates that such transformations are occurring. Carbon tetrachloride, and its degradation products chloroform, methylene chloride, and chloromethane, were reported. Similarly, tetrachloroethene was reported, together with its degradation products trichloroethene, dichloroethenes, and vinyl chloride. 1,1,2,2-Tetrachloroethane and its degradation product 1,1,2-trichloroethane were also detected.

Halogenated alkanes and alkenes as well as most of the other chemicals reported in Table 7-4 are considered to be very mobile in the subsurface environment. The principal exception to this is phthalates, which tend to adsorb onto soil organic carbon, or onto particle surfaces and do not readily partition into groundwater. Phthalates are notorious laboratory contaminants, and their presence in groundwater may be a laboratory artifact, although laboratory blanks from phases 1 and 2 did not indicate the presence of phthalates.

Table 7-4 also presents summary data for the inorganic chemicals that were detected in the surficial and Canal Creek aquifers. All of these chemicals were detected at concentrations above background levels, and their presence may therefore may be site-related. Because of the large number of potentially site-related chemicals, the inorganic chemicals were also screened to select chemicals of potential concern. As for organic chemicals, inorganic chemicals that were present in up to approximately 10% of the samples and were present at low concentrations were eliminated from further evaluation. The remaining chemicals (excluding those of low toxicity; bromide, calcium, chlorine, magnesium, phosphorus, potassium and sodium), were selected as chemicals of potential concern. These chemicals are identified in Table 7-4.

7.2.2.1.2 Lower Confined Unit

Table 7-5 presents summary data for the chemicals that were detected in the lower confined aquifer. Only five organic chemicals were detected, all in phase 1 samples only. According to the USGS phase 1 report (1989a), the presence of these chemicals is probably not site related, but is a result of laboratory contamination (toluene, methylene chloride, and ethylbenzene) or cross contamination of samples during shipping, sampling, and analysis (1,1,2,2-tetrachloroethane and trans-1,2-dichloroethene). USGS (1989a) concluded that the lower confined aquifer is not contaminated with organic chemicals and that it is unlikely that contaminants are present in this aquifer. None of these organic chemicals were detected in groundwater samples from any of the other three phases, which supports the conclusions of USGS. For these reasons, no organic chemicals were selected as chemicals of potential concern for the lower confined aquifer.

A variety of inorganic chemicals were detected in the lower confined unit, as shown in Table 7-5. All chemicals except boron, cadmium, copper, nickel, and nitrite/nitrate were detected at concentrations above those in the background wells, and therefore could be site related. However, it also is possible that these chemicals are not site-related. Vertical migration of chemicals from the upper aquifers to the lower aquifer may not be occurring as groundwater in the lower confined aquifer generally discharges upward into the Canal Creek aquifer. However, because they were detected in the lower confined aquifer at concentrations above background concentrations, these remaining chemicals

TABLE 7-5

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CANAL CREEK LOWER CONFINED AQUIFER

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
Organic Chemicals:			
trans-1,2-Dichloroethene (T12DCE)	1 / 10	3.9	ND
Ethylbenzene (ETC6H5)	6 / 10	1.5 - 3.3	ND
Methylene Chloride (CH2CL2)	9 / 9	1.6 - 9.4	4.8 - 8.0
1,1,2,2-Tetrachloroethane (TCLEA)	1 / 10	1.2	ND
Toluene (MEC6H5)	5 / 10	1.0 - 11.0	ND
Inorganic Chemicals:			
* Ammonia (NH3)	4 / 10	200 - 400	ND
* Ammonia+Organic Nitrogen	7 / 10	260 - 530	440 - 500
Boron (B)	1 / 10	20.0	30.0 - 50.0
Cadmium (CD)	1 / 10	1.0	6.0
Calcium (CA)	10 / 10	1,400 - 54,000	1,200 - 1,900
Chloride (CL)	3 / 10	4,400 - 11,000	4,800 - 12,000
* Chromium (CR)	1 / 10	10.0	ND
Copper (CU)	7 / 10	4.0 - 10.0	1.0 - 17.0
* Fluoride (F)	10 / 10	100 - 1,300	ND
* Iron (FE)	10 / 10	30.0 - 7,900	330 - 520
Magnesium (MG)	10 / 10	60.0 - 1,800	550 - 890
* Manganese (MN)	9 / 10	4.0 - 210	40.0 - 80.0
* Mercury (HG)	1 / 10	2.7	ND
Nickel (NI)	4 / 10	8.0 - 11.0	17.0 - 27.0
* Nitrite (NO2)	7 / 10	20.0 - 50.0	ND
Nitrite/Nitrate (NIT) (e)	5 / 10	40.0 - 200	100 - 360
Phosphorus (P4)	9 / 10	10.0 - 60.0	ND
Potassium (K)	10 / 10	750 - 96,000	1,200
Sodium (NA)	10 / 10	2,400 - 27,000	2,900 - 10,000
* Sulfate (SO4)	10 / 10	4,000 - 36,000	4,000 - 8,000
* Sulfide (SULFID)	1 / 8	1,200	ND
* Zinc (ZN)	10 / 10	6.0 - 390	28.0 - 73.0

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 1 (D,E,F); 2 (B,C); 16 (C,D).
(d) Samples: 139A and 140A.
(e) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

ND = Not detected.
* = Selected as a chemical of potential concern. See text.

(excluding those of low toxicity; calcium, chlorine, magnesium, phosphorus, potassium and sodium) were selected as chemicals of potential concern. Additional background data from the lower confined aquifer would help define the site-relatedness of the selected chemicals of potential concern.

7.2.2.1.3 Tentatively Identified Compounds (TICs)

A mass spectral library search for organic chemicals was performed on selected phase 1 groundwater samples and on all phase 3 and 4 groundwater samples from the surficial, Canal Creek, and lower confined aquifers. The chemicals tentatively identified in these samples are summarized in Table 7-6. Because of the uncertainties surrounding their identity and concentration, none of these chemicals was selected as a chemical of potential concern. Nevertheless, they do indicate that there are chemicals in the groundwater in addition to those looked for, primarily in the surficial and Canal Creek aquifers. However, these chemicals were identified infrequently (i.e., in no more than three samples) and generally at low concentrations (most less than 25 µg/L), and therefore may not represent significant contamination relative to the other chemicals detected in the groundwater of the Canal Creek study area.

7.2.2.2 Salvage Yard

Eight wells were sampled in the Salvage Yard area. All of these wells were located in the Canal Creek aquifer. As discussed previously, the groundwater wells in the Salvage Yard area were considered separately from the other monitoring wells in the Canal Creek area, because they are concentrated around a distinct location and over one-half mile from the main industrial area where the other wells were located. The sample results are summarized in Table 7-7.

Ten organic chemicals (chlorinated alkenes, alkanes, and phthalates) were detected in the Salvage Yard groundwater; and each of these was selected as a chemical of potential concern. The two organic chemicals detected at the highest concentrations were bis(2-ethylhexyl)phthalate (1,000 µg/L) and 1,1,2,2-tetrachloroethane (2,940 µg/L). Although bis(2-ethylhexyl)phthalate was selected as a chemical of potential concern for this risk assessment, it is highly unlikely that it is present at this concentration in groundwater. In fact, the maximum measured concentration for this phthalate was 1,000 µg/L, which greatly exceeds the aqueous solubility of 400 µg/L reported for this chemical by McDuffie et al. (1984). Further, as mentioned previously, phthalates tend to adsorb strongly to organic material, as well as surfaces in general, and do not migrate readily into groundwater from soil. Thus, there is a great deal of uncertainty surrounding this analytical result.

Of the inorganic chemicals detected in the Salvage Yard groundwater, all except cadmium are present at concentrations above those detected in the background wells. All inorganic chemicals except those of relatively low toxicity (calcium, chlorine, magnesium, phosphorus, potassium and sodium) were selected as chemicals of potential concern for the Salvage Yard groundwater.

7.2.3 SURFACE WATER

USGS collected surface water samples from the East Branch (four samples) and West Branch (nine samples) of Canal Creek and from the main section (three samples) of the creek which occurs below the confluence of the two branches. Two background samples were taken upstream along each of the branches, north of Magnolia Road. Data for the West Branch and the main portion of Canal Creek

TABLE 7-6

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN GROUNDWATER AT CANAL CREEK IN THE SURFICIAL, CANAL CREEK AND LOWER CONFINED AQUIFERS (a)

(Concentrations reported in ug/L)

Chemical (b)	Number of Detects (c)	Range of Reported Concentrations (d)
SURFICIAL AND CANAL CREEK AQUIFERS:		
Acetone (ACET)	1	22
2-(2H-Benzotriazol-2-yl)-4-methylphenol	1	4.0
Butyrolacetone	1	30
Chlorobenzene (CLC6H5)	2	3.0 - 17
2-Chlorophosphate Ethanol	1	27
1,2-Dibromoethene	3	3.0 - 11
4,5-Dimethylnonane	1	4.0
3,5-Dimethyloctane	1	3.0
Dioctyl Ester Hexanedioic Acid	3	13 - 140
1,4-Dithiane	3	2.0 - 6.0
Docosane	1	5.0 - 8.0
Ethyl Ether	3	5.0 - 33
2-Ethyl-hexanoic Acid	4	3.0 - 17
2-Ethyl-4-methyl-1,3-dioxolane	1	2.0
Ethyl Urea	1	4.0
Hexadecane	1	2.0
Heptadecane	1	6.0
2-Methyl-2,2-dimethyl-1-(2-hydroxy-1-methylethyl)propyl Ester Propanoic Acid	1	3.0
2-Methyl-2-hexanol	1	4.0
2-Methyl-3-hydroxy-2,4,4-trimethyl Pentyl Ester Propanoic Acid	1	2.0
2-Methyl-1-penten-3-ol	2	3.0
1-Methyl-2-propyl Cyclohexane	2	10 - 11
1-Methyl-2-pyrrolidinone	2	3.0 - 6.0
Methylbenzene	1	4.0
Octane	1	5.0
1,1'-Oxybis Benzene	1	4.0
Pentachloroethane (CL5ET) (e)	3	2.5 - 20.5
2-Propanol (2PROL) (e)	2	30.0 - 200
2-Propyl-1,3-dioxolane	1	8.0
Sulfur (S)	1	1.0
1,1,2,2-Tetrachloroethane (TCLEA)	2	4.0 - 21
Tetrachloroethene (TCLEE)	2	2.0 - 9.0
1,2,3,4-Tetrahydro-5-methyl Naphthalene	1	4.0
2,6,10,14-Tetramethylpentadecane	1	5.0
Tribromoethene	2	81 - 220
Xylenes [Total] (XYLEN) (e)	1	2.0
LOWER CONFINED AQUIFER:		
Bromide	1	140

(a) Data obtained from USGS (1990), except as noted.
(b) USATHAMA chemical codes listed in parentheses.
(c) Number of samples in which the chemical was tentatively identified.
(d) Samples: 1 (B,C); 4B; 5C; 7 (A,B); 13A; 16A; 17A; 18A; 20 (A,D); 25A; 28A; 107B; 110A; 111 (A,B); 115A; 120 (A,B); W6.

TABLE 7-7

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CANAL CREEK SALVAGE YARD

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
Organic Chemicals:			
* Chloroform (CHCL3)	5 / 6	1.4 - 4.0	ND
* 1,1-Dichloroethene (11DCE)	1 / 6	2.8	ND
* trans-1,2-Dichloroethene (T12DCE)	1 / 6	161	ND
* Di-n-octylphthalate (DNOP)	1 / 1	73.0	ND
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 1	1,000	ND
* Methylene Chloride (CH2CL2)	6 / 6	2.2 - 28.0	4.8 - 8.0
* 1,1,2,2-Tetrachloroethane (TCLEA)	3 / 6	1.9 - 2,940	ND
* 1,1,2-Trichloroethane (112TCE)	1 / 6	43.5	ND
* Trichloroethene (TRCLE)	2 / 6	42.8 - 450	ND
* Vinyl chloride (C2H3CL)	1 / 6	2.5	ND
Inorganic Chemicals:			
* Ammonia (NH3)	3 / 8	280 - 380	ND
* Ammonia+Organic Nitrogen	8 / 8	500 - 1,400	440 - 500
* Beryllium (BE)	1 / 8	4.0	ND
* Boron (B)	6 / 8	50.0 - 110	30.0 - 50.0
Cadmium (CD)	1 / 8	3.0	6.0
Calcium (CA)	8 / 8	5,000 - 63,000	1,200 - 1,900
Chloride (CL)	8 / 8	17,000 - 83,000	4,800 - 12,000
* Chromium (CR)	8 / 8	6.0 - 89.0	ND
* Copper (CU)	8 / 8	8.0 - 80.0	1.0 - 17.0
* Fluoride (F)	8 / 8	130 - 630	ND
* Iron (FE)	8 / 8	10.0 - 810	330 - 520
Magnesium (MG)	8 / 8	40.0 - 12,000	550 - 890
* Manganese (MN)	7 / 8	58.0 - 370	40.0 - 80.0
* Nickel (NI)	6 / 8	8.0 - 610	17.0 - 27.0
* Nitrite (NO2)	3 / 8	50.0 - 480	ND
* Nitrite/Nitrate (NIT) (e)	7 / 8	150 - 830	100 - 360
Phosphorus (P4)	8 / 8	10.0 - 20.0	ND
Potassium (K)	8 / 8	1,200 - 250,000	1,200
* Selenium (SE)	4 / 8	2.0 - 5.0	ND
Sodium (NA)	8 / 8	9,700 - 130,000	2,900 - 10,000
* Sulfate (SO4)	7 / 8	17,000 - 200,000	4,000 - 8,000
* Zinc (ZN)	7 / 8	42.0 - 1,000	28.0 - 73.0

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 37A; 38A; 39 (A,B); 40A; 41A; 42A; and 43A.
(d) Samples: 139A and 140A.
(e) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

ND = Not detected.
* = Selected as a chemical of potential concern. See text.

were grouped together for this assessment, and referred to collectively as West Branch. East Branch data were treated separately.

Three rounds of samples were collected for surface water in the Canal Creek study area. Samples were analyzed for volatile and semivolatile organic chemicals and inorganic chemicals in rounds 1 and 3 and for volatile organic chemicals in round 2. The semivolatile analyses included 1,4-oxathiane, dithiane, dinitrotoluene, and selected pesticides. The round 2 samples were collected in December 1989 when the creek was covered with about 3-4 inches of ice. Samples were collected at this time since the ice cover would inhibit volatilization of organic chemicals, thereby providing a good indication of the presence of volatile organic compounds. A library search was conducted in the first and third round for selected samples collected in areas of suspect contamination.

Surface water sampling results are discussed below for the East and West Branches.

7.2.3.1 East Branch of Canal Creek

Table 7-8 presents summary sampling data for the East Branch of Canal Creek along with the chemical concentrations detected in background samples. Seven volatile organic chemicals were detected at relatively low concentrations (<25 μg/L) in the samples collected along the East Branch of Canal Creek. These chemicals are chlorobenzene, 1,1,2,2-tetrachloroethane, methylene chloride, and trichloroethene and its degradation products trans-1,2-dichloroethene, 1,1-dichloroethene, and vinyl chloride. All of these chemicals were also measured in the Canal Creek aquifer, which is hydraulically connected to the East Branch of Canal Creek. Discharge from the aquifer to the East Branch is believed to be minimal (USGS 1989d), but the presence of these volatile chemicals in surface water suggests that some discharge is occurring. Once discharged into surface water, the most significant loss of these chemicals would occur through volatilization. In an aerobic surface water system, losses through biodegradation would not be expected to be as important as losses through volatilization. All organic chemicals detected were selected as chemicals of potential concern.

A variety of inorganic chemicals were detected in the East Branch samples. Of these, aluminum, arsenic, bromide, manganese and nitrogen were detected within the range of background concentrations for the creek. All of the remaining chemicals (except those of low toxicity; calcium, chlorine, magnesium, phosphorus, potassium, and sodium) were selected as chemicals of potential concern.

7.2.3.2 West Branch of Canal Creek

Table 7-9 summarizes surface water sampling data for the West Branch of Canal Creek along with the chemical concentrations detected in background samples. In contrast to the East Branch samples, a large number (24) of organic chemicals were detected in the surface waters of the West Branch. These chemicals are alkyl aromatics (benzene, ethyl benzene, and toluene), a halogenated aromatic (chlorobenzene), halogenated alkanes (trihalomethanes, carbon tetrachloride, methylene chloride, di-, tri- and tetrachloroethanes, and 1,2-dichloropropane), halogenated alkenes (tetrachloroethene, trichloroethene, dichloroethenes, vinyl chloride, and 1,3-dichloropropene), and a phthalate (butylbenzylphthalate). With the exception of the trihalomethanes bromoform, bromodichloromethane, and dibromochloromethane and the freon trichlorofluoromethane, these chemicals were also measured in groundwater of the Canal Creek aquifer and the surficial aquifer, which is known to discharge to the West Branch of Canal Creek.

TABLE 7-8

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER IN THE EAST BRANCH OF CANAL CREEK

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
Organic Chemicals:			
* Chlorobenzene (CLC6H5)	2 / 4	1.4	1.5
* 1,1-Dichloroethene (11DCE)	1 / 4	7.0	ND
* trans-1,2-Dichloroethene (T12DCE)	2 / 4	2.3 - 7.5	ND
* Methylene Chloride (CH2CL2)	4 / 4	2.9 - 17.4	7.9 - 14.8
* 1,1,2,2-Tetrachloroethane (TCLEA)	3 / 4	11.7 - 24.0	ND
* Trichloroethene (TRCLE)	3 / 4	3.0 - 10.3	ND
* Vinyl Chloride (C2H3CL)	1 / 4	1.4	ND
Inorganic Chemicals (e):			
Aluminum (AL)	4 / 4	198 - 317	300 - 335
Arsenic (AS)	3 / 4	0.8 - 1.2	1.7
* Barium (BA)	4 / 4	40.7 - 80.3	42.7 - 51.9
* Beryllium (BE)	2 / 4	7.3 - 11.8	10.8
* Boron (B)	1 / 4	295	ND
Bromide (BR)	4 / 4	55.0 - 66.4	70.3
* Cadmium (CD)	1 / 4	1.9	ND
Calcium (CA)	4 / 4	30,500 - 74,000	16,300 - 25,000
Chloride (CL)	4 / 4	34,500 - 44,000	20,800 - 36,500
* Chromium (CR)	2 / 4	1.0 - 13.0	2.0
* Copper (CU)	4 / 4	3.0 - 8.0	2.0
* Fluoride (F)	4 / 4	173 - 255	124 - 152
* Iron (FE)	4 / 4	1,210 - 2,450	1,750 - 2,330
* Lead (PB)	4 / 4	3.9 - 7.6	ND
Magnesium (MG)	4 / 4	9,350 - 12,800	7,400 - 7,970
Manganese (MN)	4 / 4	110 - 147	142 - 360
* Nickel (NI)	4 / 4	1.3 - 8.6	3.0 - 4.0
* Nitrite/Nitrate (NIT) (f)	4 / 4	101 - 440	20.0 - 45.0
Nitrogen (N)	4 / 4	180 - 1,050	2,550
Phosphorus (P4)	4 / 4	40.0 - 470	70.0 - 90.0
Potassium (K)	4 / 4	3,300 - 4,500	2,600 - 3,850
* Silver (AG)	1 / 4	0.5	ND
Sodium (NA)	4 / 4	21,500 - 32,000	11,000 - 26,000
* Sulfate (SO4)	4 / 4	33,000 - 41,500	20,000 - 21,000
* Zinc (ZN)	4 / 4	34.9 - 60.0	29.4 - 38.3

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 16, 17, 18 and 19.
(d) Samples: 32 and 33.
(e) Total concentrations reported.
(f) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

ND = Not detected.
* = Selected as a chemical of potential concern. See text.

TABLE 7-9

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER IN THE WEST BRANCH OF CANAL CREEK

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
ORGANIC CHEMICALS:			
Alkyl aromatics:			
Benzene (C6H6)	1 / 12	3.4	ND
* Ethyl Benzene (ETC6H5)	5 / 12	2.7 - 13.8	ND
Toluene (MEC6H5)	1 / 12	4.2	ND
Halogenated aromatics:			
* Chlorobenzene (CLC6H5)	5 / 12	2.0 - 3.5	1.5
Halogenated alkanes:			
Bromodichloromethane (BRDCLM)	1 / 12	4.6	ND
Bromoform (CHBR3)	1 / 12	6.0	ND
* Carbon Tetrachloride (CCL4)	7 / 12	2.0 - 11.0	ND
* Chloroform (CHCL3)	9 / 12	1.9 - 15.6	8.0
Dibromochloromethane (DBRCLM)	1 / 12	5.3	ND
1,1-Dichloroethane (11DCLE)	1 / 12	4.0	ND
1,2-Dichloroethane (12DCLE)	1 / 12	6.1	ND
1,2-Dichloropropane (12DCLP)	1 / 12	5.0	ND
* Methylene Chloride (CH2CL2)	12 / 12	2.8 - 15.5	7.9 - 14.8
* 1,1,2,2-Tetrachloroethane (TCLEA)	8 / 12	1.7 - 11.5	ND
1,1,1-Trichloroethane (111TCE)	1 / 12	4.1	ND
1,1,2-Trichloroethane (112TCE)	1 / 12	4.9	ND
* Trichlorofluoromethane (CCL3F)	2 / 12	3.3 - 4.5	ND
Halogenated alkenes:			
1,1-Dichloroethene (11DCE)	1 / 12	4.9	ND
* trans-1,2-Dichloroethene (T12DCE)	2 / 12	4.6 - 5.9	ND
* 1,3-Dichloropropene (13DCPE)	2 / 12	2.3 - 5.5	ND
* Tetrachloroethene (TCLEE)	3 / 12	2.0 - 4.1	ND
* Trichloroethene (TRCLE)	7 / 12	2.3 - 7.4	ND
* Vinyl Chloride (C2H3CL)	2 / 12	1.4 - 2.0	ND
Phthalates:			
* Butylbenzylphthalate (BBZP)	4 / 6	11.2 - 25.7	ND

See footnotes on the following page.

TABLE 7-9 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER IN THE WEST BRANCH OF CANAL CREEK

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
INORGANIC CHEMICALS (e):			
* Aluminum (AL)	12 / 12	231 - 2,400	300 - 335
Antimony (SB)	1 / 12	12.0	4.0
* Arsenic (AS)	9 / 12	1.1 - 3.8	1.7
* Barium (BA)	12 / 12	19.1 - 106	42.7 - 51.9
Beryllium (BE)	1 / 12	15.6	10.8
Boron (B)	1 / 12	309	ND
Bromide (BR)	9 / 12	62.1 - 2,480	70.3
* Cadmium (CD)	2 / 12	1.8 - 2.7	ND
Calcium (CA)	12 / 12	19,000 - 53,000	16,300 - 25,000
Chloride (CL)	12 / 12	32,500 - 1,260,000	20,800 - 36,500
* Chromium (CR)	9 / 12	1.3 - 13.0	2.0
* Copper (CU)	11 / 12	5.7 - 11.0	2.0
* Cyanide (CYN)	1 / 11	7.5	ND
* Fluoride (F)	11 / 12	77.8 - 363	124 - 152
Iron (FE)	12 / 12	1,060 - 2,200	1,750 - 2,330
* Lead (PB)	12 / 12	5.7 - 23.1	ND
Magnesium (MG)	12 / 12	7,250 - 84,300	7,400 - 7,970
* Manganese (MN)	12 / 12	77.0 - 612	142 - 360
* Mercury (HG)	1 / 12	0.5	ND
* Nickel (NI)	11 / 12	2.0 - 9.1	3.0 - 4.0
* Nitrite/Nitrate (NIT) (f)	9 / 12	23.2 - 775	20.0 - 45.0
Nitrogen (N)	12 12	30.0 - 1,300	2,550
Phosphorus (P4)	12 / 12	30.0 - 567	70.0 - 90.0
Potassium (K)	11 / 11	3,100 - 53,000	2,600 - 3,850
* Silver (AG)	3 / 12	0.5 - 0.6	ND
Sodium (NA)	12 / 12	18,000 - 604,000	11,000 - 26,000
* Sulfate (SO4)	12 / 12	12,000 - 44,000	20,000 - 21,000
Thallium (TL)	1 / 12	50.4	ND
* Zinc (ZN)	12 / 12	30.6 - 159	29.4 - 38.3

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 and 31.
(d) Samples: 32 and 33.
(e) Total concentrations reported.
(f) Concentration is reported as nitrite/nitrate non-specific. The values reported is assumed to represent represent the total concentration of nitrite/nitrate.

ND = Not detected.
* = Selected as chemical of potential concern. See text.

With the exception of butylbenzylphthalate, the most significant loss of these chemicals from surface water would occur through volatilization. For the phthalate, losses through biodegradation would be expected to be most significant. Saeger and Tucker (1976) found that butylbenzylphthalate underwent rapid primary biodegradation in unacclimated river water, forming the monoester, phthalic acid, and ultimately carbon dioxide.

Due to the large number of organic chemicals detected, the low frequency (1/12 in this case), and low concentration screen employed for previously for soils, was used to produce a subset of chemicals for evaluation. The organic chemicals of potential concern are identified in Table 7-9.

Twenty-nine inorganic chemicals were detected in the West Branch samples. Of these, only nitrogen and iron were detected at levels similar to those detected in background samples. Because of the large number of potentially site-related inorganic chemicals, those detected infrequently (1/12 samples) and at low concentrations were not considered further. These chemicals are antimony, beryllium, and thallium. Even though they were detected infrequently, mercury and cyanide were evaluated because they are relatively toxic to aquatic life. The remaining inorganic chemicals (excluding those of low toxicity; bromide, calcium, chlorine, magnesium, nitrogen, phosphorus, potassium, and sodium) were also selected as chemicals of potential concern.

A comparison of the number of chemicals detected in the East and West Branches, and the frequencies of detection indicates that the West Branch of Canal Creek is significantly more contaminated than the East Branch. This is not unexpected, given that the West Branch of Canal Creek received direct discharge of a variety of wastes in the past and currently receives direct discharge of contaminated groundwater from the surficial and Canal Creek aquifers.

7.2.3.3 Tentatively Identified Compounds (TICs)

Several TICs were detected in West and East Branch samples. Table 7-10 presents analytical data for these chemicals. These TICs were reported infrequently (one or two samples) and at low concentrations (generally less than 30 µg/L). The exceptions to this are butyrolacetone, which was reported in seven samples at concentrations up to 53 µg/L and mono(2-ethylhexyl)ester hexanedioic acid, which was reported in a single sample at a concentration of 80 µg/L. None of the TICs were selected for further evaluation in this risk assessment.

7.2.4 SEDIMENT

AEHA sampled sediment from six locations in the Canal Creek study area. Because no background samples were collected during either of the two studies, chemical concentrations from regional sampling were used when comparing site samples to expected background concentrations. A summary of the chemicals detected in sediment samples along with regional background concentrations of these chemicals is presented in Table 7-11.

Chlorinated pesticides such as dieldrin and DDT and its metabolites (DDD, DDE) were measured in sediment together with hexachlorobenzene, PCBs, TCPU, and 2,4,6-trichloroaniline (TCA). Several of the chemicals were detected at elevated concentrations, including Aroclor 1260 (3,260 ug/kg), TCPU (66,000 ug/kg), and TCA (1,300 ug/kg). All these chemicals exhibit a tendency to adsorb to the organic carbon present in sediment, and would therefore be transported in Canal Creek through the suspension and movement of sediment downstream from source areas. In addition, TCA would

TABLE 7-10

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN CANAL CREEK SURFACE WATER

(Concentrations reported in ug/L)

Chemical (a)	Number of Detects (b)	Range of Reported Concentrations
WEST BRANCH (c)		
Acetone (ACET)	3	3.0
Butyrolacetone	7	11 - 53
1,4-Dioxane (14DIOX)	1	14
Fluorobenzene	1	31
Hexane (HEXANE)	2	5.0 - 15
2-Hexanone (MNBK)	1	3.0
4-Methyl-2-pentanone	2	6.0 - 23
Mono(2-ethylhexyl)ester Hexanedioic Acid	1	80
N,N-Diethyl-3-methyl Benzamide	1	10
Thiobismethane	1	4.0
Xylene (XYLEN)	1	2.0
EAST BRANCH (d)		
Butyrolacetone	1	10
1,5-Dimethyl-bicyclo-3-2-2-nona-6,8-dien-3-one	1	2.0
Hexane (HEXANE)	1	10

(a) USATHAMA chemical codes in parentheses.
(b) Number of samples in which the chemical was tentatively identified.
(c) Samples: 20-25, 28-30.
(d) Samples: 17-19.

TABLE 7-11

SUMMARY OF CHEMICALS DETECTED IN SEDIMENT SAMPLES AT CANAL CREEK

(Concentrations reported in ug/kg for organics, and in mg/kg for inorganics)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
Organic Chemicals:			
* DDT [Total]	3 / 6	19.0 - 220	NA
* o,p'-DDD (OPDDD)	1 / 3	220	NA
* o,p'-DDT (OPDDT)	1 / 3	20.0	NA
* p,p'-DDD (PPDDD)	3 / 6	19.0 - 520	NA
* p,p'-DDE (PPDDE)	2 / 3	30.0 - 270	NA
* p,p'-DDT (PPDDT)	1 / 3	70.0	NA
* Dieldrin (DLDRN)	1 / 6	60.0	NA
* Hexachlorobenzene (CL6BZ)	3 / 6	12.0 - 35.0	NA
* PCB [Total]	4 / 6	715 - 5,680	90 - 120 (e)
* Aroclor-1242 (PCB242)	3 / 6	265 - 460	NA
* Aroclor-1254 (PCB254)	1 / 6	2,510	NA
* Aroclor-1260 (PCB260)	4 / 6	350 - 3,260	NA
* TCPU	3 / 3	36,000 - 66,000	NA
* 2,4,6-Trichloroaniline (246TCA)	3 / 3	600 - 1,300	NA
Inorganic Chemicals:			
* Arsenic (AS)	6 / 6	14.4 - 94.9	14 - 46
* Beryllium (BE)	3 / 6	4.2 - 6.3	NA
* Cadmium (CD)	5 / 6	1.6 - 3.9	0.005 - 1.1
* Chromium (CR)	6 / 6	30.8 - 200	50 - 69
* Copper (CU)	6 / 6	25.0 - 185	41 - 45
Iron (FE)	3 / 3	16,600 - 25,100	4,000 - 45,000
* Lead (PB)	6 / 6	125 - 527	42 - 66
* Mercury (HG)	5 / 6	0.1 - 5.7	0.1 - 0.3
* Nickel (NI)	3 / 6	26.8 - 68.5	37 - 57
Selenium (SE)	3 / 6	0.4 - 0.5	0.92 - 1.3 (e)
* Thallium (TL)	1 / 6	65.0	NA
* Zinc (ZN)	6 / 6	133 - 894	200 - 220

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed for that chemical.
(c) Samples: CC1, CC2, CC3, EA-K, EA-L and EA-R.
(d) Range of concentrations in sediment reported for two monitoring stations in the Bush and Gunpowder Rivers, except as noted. Data derived from Maryland Chesapeake Bay Toxicant Monitoring Program. See text.
(e) Background concentrations from the Chesapeake Bay (Maryland Chesapeake Bay Toxicant Monitoring Program).

NA = Not available.
* = Selected as a chemical of potential concern. See text.

partition from sediment into surface water to a greater extent than chlorinated pesticides, hexachlorobenzene, and TCPU. TCA therefore, can also migrate by partitioning into surface water and migrating downstream from sediment sources.

There is some question whether the TCA was actually present in sediment, because this chemical may be produced by the thermal degradation of TCPU during analysis with gas chromatography. Harvey et al. (1990) investigated the potential biodegradation of TCPU to TCA using high-performance liquid chromatography, which would not cause thermal degradation during analysis.[3] Over a 2-month period during which degradation of TCPU to TCA was measured in spiked, unacclimated sediment, no clear indication of TCA formation was found. Some TCA was measured during the course of the study, but the concentration of TCA did not increase over time and thus may have resulted from thermal degradation when sediments were oven-dried. While the authors concluded that TCA was not formed in the sediments as a result of biodegradation, it is unclear at this time whether such degradation could occur in the environment under conditions different from those imposed in the study. For example, dissolved oxygen was low during the course of the study, and in a more aerated surface water body, degradation might be facilitated. In addition, microbes may require an acclimation period to TCPU greater than the 2-month period in the study, before degradation can occur. Because of the length of time TCPU has remained in the sediments in Canal Creek, some microbial degradation to TCA may have occurred. In addition, TCA was a major intermediate in the manufacture of N,N'-dichloro-bis(2,4,6-trichlorophenyl)urea (CC2) during the 1920s and early 1930s, and was present in waste disposed of in the Canal Creek swamp. Because of these uncertainties, TCA was considered a chemical of potential concern in this analysis (rather than an analytical artifact), together with all of the other organic chemicals measured in the sediment of Canal Creek.

Twelve inorganic chemicals were detected in the sediment samples, as shown in Table 7-11. Of these, iron and selenium were within the range of background concentrations, and were thus eliminated as chemicals of potential concern. All other inorganic chemicals were selected as chemicals of potential concern for Canal Creek sediments.

7.2.5 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Table 7-12 summarizes the chemicals of potential concern for each medium sampled in the Canal Creek study area. Volatile organic compounds and inorganic chemicals were selected as the primary chemicals of potential concern in groundwater and surface water. Pesticides, PCBs, TCPU, TCA, hexachlorobenzene, and inorganic chemicals were selected as the chemicals of potential concern in soil and/or sediment. Most of the chemicals in groundwater were detected in samples from the Canal Creek and surficial aquifers; the lower confined aquifer contained elevated levels only of some inorganic chemicals. However, as mentioned previously, the presence of these inorganic chemicals in the lower confined aquifer may reflect natural background levels rather than site-related contamination.

In addition to the chemicals of potential concern selected for each medium, other chemicals are likely to be present in the Canal Creek study area, and may be of potential concern regarding possible

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[3] The authors referred to their synthesized compound, N,N'-bis(2,4,6-trichlorophenyl)urea or TCPU, as CC-2. The clothing impregnating agent known as CC-2 is N,N'-dichloro-bis(2,4,6-trichlorophenyl) urea. It is clear from the discussion, however, that Harvey and co-workers synthesized and studied TCPU.

TABLE 7-12

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR CANAL CREEK

		Groundwater			Surface Water		
Chemical (a)	Soil	Surficial and Canal Creek Aquifers	Lower Confined Aquifer	Salvage Yard	East Branch	West Branch	Sediment
ORGANIC CHEMICALS:							
Alkyl aromatics:							
Benzene (C_6H_6)		X					
Ethyl Benzene (ETC_6H_5)		X				X	
Halogenated aromatics:							
4-Bromofluorobenzene (4BFB)		X					
Chlorobenzene (CLC_6H_5)		X			X	X	
Hexachlorobenzene (CL_6BZ)							X
2,4,6-Trichloroaniline (246TCA)							X
Cyclic sulfur compounds:							
Dithiane (DITH)		X					
1,4-Oxathiane (OXAT)		X					
Ethers:							
bis(2-Chloroethyl)ether (B2CLEE)		X					
Halogenated alkanes:							
Carbon Tetrachloride (CCL_4)		X				X	
Chloroform ($CHCL_3$)		X		X		X	
1,2-Dichloroethane (12DCLE)		X					
Methylene Chloride (CH_2CL_2)		X		X	X	X	
1,1,2,2-Tetrachloroethane (TCLEA)		X		X	X	X	
1,1,2-Trichloroethane (112TCE)		X		X			
Trichlorofluoromethane (CCL_3F)	X					X	
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	X						
Halogenated alkenes:							
1,1-Dichloroethene (11DCE)				X	X		
cis-1,2-Dichloroethene (C12DCE)		X					
trans-1,2-Dichloroethene (T12DCE)		X		X	X	X	
1,3-Dichloropropene (13DCP)						X	
Tetrachloroethene (TCLEE)		X				X	
Trichloroethene (TRCLE)		X		X	X	X	
Vinyl Chloride (C_2H_3CL)		X		X	X	X	
Nitro aromatics:							
Nitrobenzene (NB)		X					
Phthalates:							
Butylbenzylphthalate (BBZP)		X				X	
Di-n-butylphthalate (DNBP)	X						
Di-n-octylphthalate (DNOP)				X			
bis(2-Ethylhexyl)phthalate (B2EHP)		X		X			
Ureas:							
TCPU							X

See footnotes on the following page.

TABLE 7-12 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR CANAL CREEK

Chemical (a)	Soil	Groundwater			Surface Water		Sediment
		Surficial and Canal Creek Aquifers	Lower Confined Aquifer	Salvage Yard	East Branch	West Branch	
ORGANIC CHEMICALS (cont.):							
Chlorinated pesticides/PCBs:							
Dieldrin (DLDRN)							X
DDT [Total]							X
o,p'-DDD (OPDDD)							X
o,p'-DDT (OPDDT)							X
p,p'-DDD (PPDDD)							X
p,p'-DDE (PPDDE)	X						X
p,p'-DDT (PPDDT)							X
PCB [Total]							X
Aroclor 1242 (PCB242)							X
Aroclor 1254 (PCB254)							X
Aroclor 1260 (PCB260)							X
INORGANIC CHEMICALS:							
Aluminum (AL)		X				X	
Ammonia (NH3)		X	X	X			
Ammonia+Organic Nitrogen		X	X	X			
Antimony (SB)	X	X					
Arsenic (AS)	X	X				X	X
Barium (BA)		X			X	X	
Beryllium (BE)				X	X		X
Boron (B)		X		X	X		
Cadmium (CD)		X			X	X	X
Chromium (CR)	X	X	X	X	X	X	X
Copper (CU)	X	X		X	X	X	X
Cyanide (CN)						X	
Fluoride (F)		X	X	X	X	X	
Iron (FE)	X	X	X	X	X		
Lead (PB)	X	X			X	X	X
Manganese (MN)	X	X	X	X		X	
Mercury (HG)	X	X	X			X	X
Nickel (NI)		X		X	X	X	X
Nitrite (NO2)		X	X	X			
Nitrite/Nitrate [non specific] (NIT)		X		X	X	X	
Selenium (SE)	X			X			
Silver (AG)					X	X	
Sulfate (SO4)		X	X	X	X	X	
Sulfide (SULFID)		X	X				
Thallium (TL)							X
Zinc (ZN)	X	X	X	X	X	X	X

(a) USATHAMA chemical codes listed in parentheses.

X = Selected as a chemical of potential concern.

Note: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium, (2) it was not included in the analyses, or (3) it was detected at background concentrations (inorganic chemicals only). See text for this information.

exposures and impacts. Table 7-13 identifies the additional chemicals potentially of concern for the Canal Creek study area that either were not included in the chemical analyses or were not analyzed for in specific media. The chemicals listed are those that have the potential of being present in the greatest quantities based on historical information (AEHA 1989).

Many chemicals were used at Canal Creek in the various pilot and manufacturing plants and laboratories, but it is assumed that these areas are not as contaminated as the disposal pits where many of the wastes were placed. As a result, this list focuses on the chemicals likely to be found in the disposal areas. In addition, a large number of other chemicals could be present in smaller quantities, having been disposed of in conjunction with other wastes, and therefore could also contribute to potential exposures and risks.

Large quantities of chemicals and their wastes were disposed of in the Canal Creek study area. In many cases, chemicals were disposed of in containers or in materials that inhibited natural degradation. For example, in many cases, pipes containing mustard residue were disposed of in pits, protecting it from degradation processes. Lethal chemical agents, such as mustard, lewisite, phosgene, and G-agents (tabun and soman) were often disposed of in munitions or laboratory equipment, and may still be present. Although phosgene is readily hydrolyzed and not likely to be persistent, it may have been disposed of in containers, preventing its degradation.

There is little information on the microbial degradation of many of the chemicals used or disposed of in the Canal Creek area. Chloropicrin and chloroacetophenone could be mobile in the environment. These chemicals probably have an environmental mobility comparable to several VOCs measured in groundwater. Adamsite tends to form a protective oxide coating in water that would retard hydrolysis to HCl and diphenylarsenious oxide. White phosphorus, which was disposed of in great quantities in the marshy areas, has been unearthed several times during maintenance work. TCPU was found in sediment along the mouth of Canal Creek (USAMBRDL 1983). Also, it is unclear whether the clothing impregnite, CC2 (N,N'-di-chlorobis[2,4,6-trichlorophenyl]urea) is present in sediment, since no fate information was located for this chemical.

7.3 HUMAN HEALTH RISK ASSESSMENT

This section addresses the potential human health risks associated with the Canal Creek study area in the absence of remedial actions. This human health risk assessment is divided into three principal sections. Section 7.3.1 evaluates the potential human exposures and the magnitude of exposures for the chemicals of potential concern at the site. Section 7.3.2 summarizes the relevant toxicity information for the chemicals of potential concern. Finally, Section 7.3.3 provides quantitative and qualitative estimates of human health risks.

7.3.1 EXPOSURE ASSESSMENT

This section identifies the pathways by which human populations may be exposed to chemicals of potential concern at or originating from the Canal Creek study area and describes the pathways selected for further evaluation. Only complete pathways were selected for further evaluation. Evaluations of exposures may be quantitative or qualitative, depending upon several factors, including probability of exposure, the potential magnitude of exposure, and the availability of data to support quantitative evaluations. Exposure point concentrations and daily intakes were estimated for all pathways selected for quantitative evaluation.

TABLE 7-13

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT CANAL CREEK (a)

Group	Chemical	Comments
Lethal Chemical Agents	Mustards (H, HD) (and nitrogen mustards) Lewisite (L) Phosgene (CG) Tabun (GA)	No media have been analyzed for these chemicals, however these chemicals could be present in the Canal Creek study area. Historical information indicates that large amounts of mustard were disposed of in pits and in the marshy landfill. In some pits mustard could still be present in mustard storage tanks, old pipes, in items plugged with solidified sulfur and mustard, or in munitions. If mustard were containerized (e.g., in old pipes or munitions), it could still be present, being protected from degradation processes, such as hydrolysis and volatilization. In addition, where large quantities of mustard were released (e.g., mustard plant waste pit), some mustard could still remain, if it had not yet undergone the degradation processes. Lewisite may still be present in containers or contaminated items that were placed into disposal pits or the marshy landfill, or in the soil. Where protected from environmental degradation processes (such as in the soil or in containers), Lewisite could persist for decades. Tabun could remain in disposal pits if decontamination of laboratory items was not complete or if they were containerized.
Agent Breakdown Products	Thiodiglycol 1,4-Dithiane Lewisite Oxide Chlorovinylarsonic Acid	These compounds are degradation products of mustard (thiodiglycol and 1,4-dithiane) and lewisite (lewisite oxide and chlorovinylarsonic acid). They were not analyzed for in any media in the Canal Creek study area. However, given the large quantities of mustard and lewisite disposed of in the Canal Creek area, these chemicals are potentially present in groundwater and could be present in surface water in areas where groundwater is discharging to surface water.
Incapacitating Agents	Chlorpicrin (PS) Chloroacetophenone (CN) Adamsite (DM)	No media have been analyzed for these chemicals. However, based on the disposal history of Canal Creek, these chemicals could be present in groundwater and surface water. Chloropicrin and chloroacetophenone each have solubilities comparable to VOCs measured in groundwater. In addition, these chemicals are relatively stable with respect to hydrolysis, and would not adsorb appreciably to soil. Therefore, these chemicals would be mobile in the subsurface, and could be present in groundwater. In a surface water environment, chloropicrin would volatilize to the same extent as VOCs such as methylene chloride. Chloroacetophenone would not volatilize readily however, and would migrate with surface water. Some chemical transformations could potentially occur. Adamsite persists for long periods in both water and soil, as a result of a protective film of DM oxide on the surface of solid DM.
Smoke/Incendiary Materials	White Phosphorus	White phosphorus, which was disposed of in great quantities, is persistent in anaerobic environments. Large amounts of white phosphorus were buried in sediments, and white phosphorus is still present in soils (workers have dug into soils containing white phosphorus in recent years).
CC2 Clothing Impregnating Materials	TCPU	TCPU is persistent in the environment, and has been found in sediments along the mouth of Canal Creek, where it flows into the Gunpowder River. However, sediments in the Gunpowder River near the mouth of Canal Creek have not been sampled and therefore, the extent of contamination is unknown.
	CC2	CC2 was not analyzed in any media in the Canal Creek study area. CC2 was manufactured in large quantities in the Canal Creek area and could be present in sediments in Canal Creek and the Gunpowder River. No fate information was located for this chemical.
Miscellaneous Compounds/	PCBs	PCBs were found in sediment samples, but were not detected in surface soils (it should be noted however, that the detection limit for PCBs during laboratory analysis for soils was very high).

(a) Based on historical information. Chemicals listed are those potentially present in the greatest quantities. A large number of other chemicals could be present in smaller quantities at Canal Creek.

This exposure assessment is organized into three principal sections. Section 7.3.1.1 discusses potential exposure pathways under current land-use conditions, and Section 7.3.1.2 discusses those potentially occurring under hypothetical future land-use conditions. Section 7.3.1.3 presents estimates of potential human exposures for those pathways selected for quantitative evaluation.

7.3.1.1 Potential Exposure Pathways Under Current Land-Use Conditions

Approximately 75% of the land in the Canal Creek study area is developed; it contains buildings, paved areas, and grassy, landscaped areas. The areas of Canal Creek where military personnel and civilians work are primarily located in two sections of the site: between the East and West Branches of Canal Creek, and in the northeastern portion of the site, just south of the railroad tracks. In addition to laboratories and offices, the Canal Creek study area also has several residential sections (consisting of barracks and residential housing for military personnel and their families), several recreational areas, and several areas reserved for military training.

The principal recreational areas are located in the southern part of the study area. Horse stables and a horse grazing area are located along the East Branch of Canal Creek. Horses are ridden in the grazing area and along roads and paths in APG. Baseball and softball fields and tennis courts are located near the horse stables, in the southeastern portion of the study area. In addition, Capa Field, a popular picnic area is located in the southern portion of the site. This area is used frequently throughout the summer.

The only activity likely to occur near many of the main waste disposal areas in the Canal Creek study area is maintenance of sewer lines that run near the disposal pits. Other activities could occur near the Building 103 dump, one of the Building 65 pits, and parts of the marshy landfill area, which are grassed and landscaped areas. Exposures in these areas might result from mowing and digging of shrubs and trees. One of the Building 65 pits is probably located under a building. The Smoke Mixtures Burning sites are fenced, barring access to the general population.

The drinking water source for the Canal Creek study area is Winter's Run, which is located north and upgradient of the study area. Although groundwater in the Canal Creek study area was used in the past as a source of potable and industrial water, none of the groundwater wells in this area is currently in use since volatile organic contamination was discovered in six stand-by wells in the area in 1984.

It should be noted that while several private groundwater wells exist off-site of the study area, they are located upgradient of the Canal Creek area with respect to groundwater flow, and are thus unlikely to receive contaminants from the Canal Creek study area. Furthermore, the aquifer that is tapped by these upgradient wells is the deeper aquifer in the lower confined unit, which, as described above, may not be contaminated and is hydraulically independent from the contaminated surficial and Canal Creek aquifers.

Canal Creek and its East and West Branches flow through the Canal Creek study area. Persons in the Canal Creek area have easy access to the East Branch of Canal Creek, which flows through the marsh/landfill area. However, activities, like wading and swimming, that would involve contact with surface water are not likely to occur in the East Branch because of its shallow depth and intermittent flow. The dense vegetation on the banks of the West Branch limits access to the West Branch. The only areas that allow access to the West Branch are the bridges that cross the creek, and entry is difficult even there. Access to the main portion of Canal Creek from the confluence of the branches to the mouth of the Gunpowder River is also limited by heavy vegetation. People have easy access to Canal Creek at its mouth at the Gunpowder River. This area is used for fishing.

Some hunting takes place in the wooded areas in the northern and western sections of the Canal Creek study area. Because there are no paths in these wooded areas to facilitate casual use by those other than hunters, there is expected to be little other use of this wooded area. Although the wooded areas were not sampled specifically, they are not expected to be highly contaminated, since it is not believed that wastes were disposed of there.

The following sections discuss potential long-term (chronic and subchronic) and acute exposure pathways under current land-use conditions.

7.3.1.1.1 Potential Long-Term Exposure Pathways Under Current Land-Use Conditions

Table 7-14 summarizes the exposure pathways by which humans could be exposed to chemicals at or originating from the Canal Creek study area under current land-use conditions. These potential exposure pathways are discussed below by exposure medium.

Surface Soil. Exposures to chemicals in surface soil could occur via dermal contact and/or incidental ingestion of soil (as a result of hand-to-mouth contact). As the data in Table 7-2 indicate, soils in the Canal Creek study area contain several potentially site-related chemicals, and thus direct contact exposures are possible. (Inhalation exposures to chemicals that are present on wind-blown dust or that volatilize from surface soil are discussed below under the section on air.)

Of the potentially exposed populations in the Canal Creek study area, direct contact exposures are potentially greatest for workers, such as groundskeepers whose activities that could result in significant contact with chemicals in soils (e.g., digging, planting shrubs, laying sod). Utility and sewer maintenance workers also could contact soils. However, these individuals are likely to be exposed less frequently than groundskeepers, since sewer and utility maintenance is not likely to occur as often as landscaping or similar activities.

Potential exposures in other human populations in the Canal Creek study area are likely to be much less than those potentially occurring in groundskeepers. Other populations are unlikely to engage in activities that involve significant contact with soils, and soil contamination is likely to be less in the areas where contact with soils would occur. For example, office and laboratory staff in the Canal Creek study area are not likely to contact surface soils as part of their typical activities. Residents in the Canal Creek study area could contact soils while playing outside or engaged in other activities, such as gardening or yard work, but the residential area in the Canal Creek study area is over one-half mile southwest of the industrial area where most of the waste disposal activities took place and is therefore not likely to be contaminated. Persons engaged in recreational activities in Capa Field also have the potential for direct contact exposures. Data on chemical levels in soils at Capa Field are not available, but it is considered unlikely that soils in this area are contaminated because of the location of the field relative to principal waste disposal and manufacturing areas in the Canal Creek study area. This pathway was therefore not evaluated.

Direct contact exposure for groundskeepers was selected for quantitative evaluation.

TABLE 7-14

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS IN THE CANAL CREEK STUDY AREA

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Soil	Dermal absorption and/or incidental ingestion of chemicals in surface soil by grounds maintenance workers.	Moderate. Contaminants have been detected in surface soil, and there could be regular exposures to chemicals in surface soil.	Data sufficient for surface soil.	Quantitative.
Subsurface Soil	None. Although subsurface soils are likely contaminated as a result of past waste disposal, no activities that involve long-term contact with subsurface soil are likely to occur in the area.	No potential for long-term exposure.	NA. Pathway not complete.	None. No complete pathway exists.
Subsurface Soil	Acute hazards: exposure to UXO or chemical agents in subsurface environments during excavation by grounds maintenance workers or other workers (e.g., utility or sewer maintenance workers).	Negligible to high. The potential for such an exposure to occur is low because institutional controls restrict any ground-breaking activity. However, should unpermitted excavation occur and chemical agents and UXO are encountered, the potential for significant exposure is high.	Poor. Information is limited on the exact location of all waste areas and the types and quantities of agents or UXO disposed.	Qualitative.
Groundwater	None. Although chemical transport to groundwater from sources has occurred, there are no human uses of groundwater at the site or in downgradient areas.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Surface water/ sediment	Dermal contact and incidental ingestion of chemicals in surface water/sediment by persons living or working in the Canal Creek area or fishing near the mouth of Canal Creek.	Negligible. Persons are unlikely to engage in activities that involve direct contact or incidental ingestion with surface waters and sediments in Canal Creek or the Gunpowder River.	Poor. Surface water was sampled from 12 locations along an approximately 2 mile stretch of the West Branch and main portion of Canal Creek and from only 4 locations along a 2 mile stretch of the East Branch. Only 6 sediment samples were collected for the entire watershed.	None, due to low potential for exposure.

See footnotes on the following page.

TABLE 7-14 (continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS IN THE CANAL CREEK STUDY AREA

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Fish	Ingestion of fish that have accumulated chemicals in sediment and surface water by fishermen who fish along the mouth of Canal Creek.	Unknown. The area near the mouth of Canal Creek is fished frequently. However, the type and extent of contamination is unknown. Several chemicals detected in upstream portions of the creek could bioaccumulate significantly in fish.	Poor. No data available on chemical concentrations in fish living in the Gunpowder River near the mouth of Canal Creek. Only one surface water sample and two sediment samples collected from this area, and none collected from the Gunpowder River downgradient of the mouth of Canal Creek.	None, because the potential for significant exposure is unknown.
Game	Ingestion by hunters of game that has accumulated chemicals from surface water, sediment, and soil in the Canal Creek study area.	Negligible to moderate. Hunting does occur in the Canal Creek study area and chemicals that could accumulate in game species have been detected in the area. However, game from the area is unlikely to be a significant food source for hunters.	Poor. No data available on chemical concentrations in tissue of game species. Too few data available on the type and extent of contamination in areas potentially used by game species, in particular, along the Canal Creek drainage way and in the less developed, forested areas located in the northern portion of the study area.	Qualitative, due to the potential for significant exposure but lack of data to quantitatively evaluate.
Air/Dusts	Inhalation of dusts that have eroded from soil by persons living and working in the Canal Creek area.	Negligible. Dust generation and transport is unlikely because most of the study area is vegetated. The areas that do have bare soil are small in size and will not result in significant air contamination.	Poor. No air data collected.	None, due to low potential for exposure.
Air/Vapors	Inhalation of organic compounds that have volatilized from groundwater, surface water, sediment or soil by persons living and working in the Canal Creek area.	Moderate. Volatile chemicals are present in groundwater and groundwater is known to discharge to surface water. Volatile chemicals in groundwater also could be transported to air via migration through soil. Further, there is daily use in the Canal Creek area.	Poor. No ambient air samples have been collected in the Canal Creek study area. Some soil gas sampling conducted, but results are in relative concentrations and cannot be used for exposure analyses; extent of plume and location of groundwater discharge are unknown, and therefore it is not possible to model chemical emissions.	Qualitative, due to the potential for significant exposure but lack of data to quantitatively evaluate.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of current land use.
NA = Not applicable.

Subsurface Soil. Exposure to chemicals in subsurface soil could occur via dermal contact and/or incidental ingestion during activities such as excavation. No monitoring data are available on the types and concentrations of chemicals present in subsurface soil in the Canal Creek study area, but given past waste disposal practices in the Canal Creek study area, the potential for significant subsurface contamination exists. Activities that involve long-term contact with subsurface soils are unlikely to occur, however, so no complete pathway exists for long-term exposures. No pathway was selected for evaluation. (Potential acute exposures to chemicals in subsurface soils are discussed separately in the following section.)

Groundwater. There is no current use of groundwater in the Canal Creek study area or downgradient of the site. As a result, no groundwater exposure pathways exist under current land-use conditions for this area.

Surface Water/Sediment. Persons could be exposed via dermal contact or incidental ingestion to chemicals in surface water and sediment during activities such as wading or swimming. (Inhalation exposures to chemicals that have volatilized from surface water are discussed below under the section on air.) Such exposures are unlikely to occur in the East and West Branches of Canal Creek, however, because of the shallow and intermittent nature of the East Branch and the inaccessibility of the West Branch. The most likely place for surface water or sediment exposures is the mouth of Canal Creek at the Gunpowder River, where fishing occurs. However, significant direct contact and/or incidental ingestion while fishing is unlikely because people fish from the shoreline and generally do not wade into the Gunpowder River or Canal Creek. In any case, such exposures would be so infrequent as to be negligible.

Fish. There is no fishing in Canal Creek, but there is in the Gunpowder River near the mouth of Canal Creek. People could therefore be exposed to chemicals by the consumption of fish that have accumulated chemicals from surface water and sediment. The fish caught in this area would most likely live in the Gunpowder River and the lower portions of Canal Creek and not in the upstream portions of Canal Creek, near the main industrial area.

Only one surface water sample and two sediment samples were collected from near the mouth of Canal Creek, and none was collected from the Gunpowder River. Therefore, few data are available by which to estimate bioaccumulation in fish that live (and could be caught) in the Gunpowder River near the mouth of Canal Creek or in the lower portions of Canal Creek. As a result, the potential for significant exposure via this pathway is currently unknown.

One of the fish tissue samples collected by AEHA (1985) was collected from near the mouth of Canal Creek. However these data have not been published separately, but have been averaged in with two other fish tissue samples collected from upstream portions of Canal Creek (AEHA 1985), and therefore chemical levels in fish near the mouth of Canal Creek, where fish would be caught, are not known. Even if the data for this sample were available, one sample would not be adequate to evaluate potential human exposures via the ingestion of fish.

Several of the chemicals detected in sediments and surface water in upstream portions of Canal Creek could bioaccumulate significantly in fish. Chemicals of particular concern with respect to bioaccumulation and human exposures are mercury, PCBs, DDT and its metabolites, and other organochlorine pesticides. Based on physicochemical properties alone, TCPU, which is present in sediments in the Canal Creek area, also could potentially bioaccumulate significantly in fish. Because few data are available on the mammalian toxicology of TCPU, the potential significance of such exposures in unknown.

Because existing data cannot support quantitative or qualitative evaluations of exposures via ingestion of fish, this pathway was not selected for evaluation in this assessment.

Game. Persons ingesting game from the Canal Creek area, where hunting and trapping occur, could be exposed to site-related contaminants. Game could be exposed to chemicals via ingestion of surface water, ingestion of food that has accumulated chemicals, or ingestion of sediment or soil while foraging or grooming. The degree of accumulation in the game would depend on the types and concentrations of chemicals present in these media, the areal extent of contamination relative to the size of the home range of the game species, and the foraging habits of the game species. The chemicals in the Canal Creek study area of greatest concern with respect to accumulation in terrestrial game species are PCBs, DDT and its metabolites, and other organochlorine pesticides. PCBs, DDT and metabolites, and dieldrin (an organochlorine pesticide) have been detected in the sediments of Canal Creek, and DDE (a DDT metabolite) was found in surface soil.

It is not possible to quantitatively evaluate this pathway based on the available data. No data are available on chemical concentrations in the tissue of game species living in the Canal Creek area, necessitating the use of models to estimate accumulation in game species. However, data on the type and extent of contamination in areas potentially used by game species are limited and do not support the use of quantitative models. The few surface water and sediment samples from Canal Creek are not sufficient to characterize the type and extent of contamination in and along Canal Creek, and the available soil samples were collected from the industrial area of Canal Creek, which would not be used extensively by game species. Because of these data limitations, this exposure pathway was evaluated qualitatively.

Air. Air contamination in the Canal Creek study area could result from direct volatilization of chemicals and transport by wind entrainment of chemicals present on dust particles. Migration of contaminants by wind entrainment of dust particles is unlikely to be an important transport process in the Canal Creek study area because the area is almost completely vegetated or paved. The principal exception to this is the Smoke Mixtures Burning Sites, where there are several sandy areas where burning of smoke mixtures took place. Dust could be generated from these areas during windy periods, but, given the small size of this area, significant dust emissions are unlikely.

Release of volatile chemicals to the atmosphere in the Canal Creek area could occur as a result of groundwater discharge to surface water with subsequent volatilization or as a result of volatilization in subsurface environments (from groundwater, soils, or wastes) and transport through soil spaces to the atmosphere. Groundwater containing VOCs is known to discharge to Canal Creek, but the exact locations of this discharge are unknown. The most likely area would be in the vicinity of the East Branch, where the paleochannel is located, and at the West Branch, where the surficial aquifer crops out. Although many of the chemicals detected in groundwater were present at relatively low concentrations (<100 µg/L), several chemicals were detected at concentrations in excess of 1,000 µg/L and could contribute to significant air exposures. Further, even though many of the chemicals were detected at low concentrations, the sheer number of chemicals present in groundwater and potentially discharged to surface water could result in significant cumulative exposures. Surface water data did not indicate high levels of volatile chemicals. These samples may not have been collected at groundwater discharge points, however, and may reflect lower concentrations than occur at the discharge points.

Volatilization of chemicals through the soil pore spaces could result in the release of contaminants to ambient air in the Canal Creek study area. Soil gas studies in the Canal Creek area indicate that chemicals are volatilizing in the subsurface environments and are being transported in soil gas[4]. Depending on the nature of the subsurface contamination, such processes could contribute significantly to overall emissions. Further, because the groundwater plume in the Canal Creek study area is potentially large, it could contribute significantly to overall volatile emissions in the Canal Creek area.

No air samples have been collected in the Canal Creek area, and the data that are available are not sufficient to model air emissions as a result of direct discharge of volatiles to surface water or of volatilization and transport through soil. Therefore, this pathway was not evaluated quantitatively. It was selected for qualitative evaluation, however, because of the daily presence of receptors (e.g., workers) in the Canal Creek area and the potential for significant exposures.

7.3.1.1.2 Potential Acute Hazards Under Current Land-Use Conditions

Because of the large quantities of chemicals and ordnance disposed in the Canal Creek area, the potential exists for acute exposures and hazards. The most plausible scenario is exposure to buried ordnance or bulk wastes during excavation. To reduce the potential for such exposures, the APG Department of Safety requires that a permit be obtained by persons planning any activity that involves breaking of ground (e.g., construction, landscape planting, sewer maintenance). Permits are issued only after a search of historical records and other activities necessary to determine the presence of hazardous materials (e.g., magnetometer sweeps, soil gas, or soil sampling) have been completed.

Because of these institutional controls, it is probably unlikely that persons will contact acutely hazardous materials, such as chemical agent or unexploded ordnance. It is possible that excavations could take place without a Department of Safety review. In these instances, there could be acute exposures to buried chemicals as well as unexploded ordnance. Although such exposures are unlikely, they were selected for evaluation because of their potentially severe consequences. These exposures were evaluated qualitatively. Too few data are available on the quantities, types, and location of wastes disposed of in the Canal Creek study area to quantify acute exposures.

7.3.1.2 Potential Additional Exposure Pathways Under Future Land-Use Conditions

Table 7-15 summarizes the exposure pathways by which humans could be exposed to chemicals at or originating from the Canal Creek study area under future land-use conditions. The potential exposure pathways are described below.

It is unlikely that human activity in the Canal Creek study area will change significantly in the future. Expansion involving construction of new buildings in the area is not likely, considering the uncertainty regarding the exact locations of all waste disposal areas. Use of Canal Creek and its associated wetlands is also not likely to change in the future, as this area is generally not suitable.for recreational activities. Use of groundwater for potable or nonpotable uses also is not likely given the institutional knowledge of the contaminated nature of the groundwater in the Canal Creek study area. Several

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[4] The soil gas data (USGS 1989e) cannot be used to derive quantitative emission estimates because they represent the relative concentrations of various chemicals in soil gas (based on ion counts) and do not provide information on the actual chemical concentrations in soil gas (e.g., in ug/m^3).

TABLE 7-15

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER HYPOTHETICAL FUTURE LAND-USE CONDITIONS IN THE CANAL CREEK STUDY AREA

Exposure Medium	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Groundwater	Ingestion by workers of chemicals that have migrated to groundwater from waste areas.	High, if groundwater is used in the future. However, such exposure is considered extremely unlikely. Nevertheless, this pathway will be evaluated to assess the quality of groundwater as a drinking water resource.	Moderate. A large number of wells have been sampled. However, not all potential contaminants have been analyzed.	Quantitative.
Groundwater	Dermal contact with and inhalation of chemicals in groundwater used as a tap water source by workers.	Negligible to moderate if groundwater is used in the future, because many chemicals are present in groundwater that could volatilize or be dermally absorbed. Such exposures are considered extremely unlikely. Nevertheless, these pathways are evaluated to assess the quality of groundwater as a tap water resource.	Moderate. A large number of wells have been sampled. However, not all potential contaminants have been analyzed.	Qualitative.
Groundwater	Dermal contact and inhalation of chemicals that have migrated to groundwater during use of groundwater for industrial processes.	Moderate, if groundwater is used in the future, because many volatile organic chemicals are present in groundwater. However, such exposure is considered extremely unlikely. Nevertheless, this pathway will be evaluated to assess the qulity of groundwater as an industrial water resource.	Moderate. A large number of wells have been sampled. However, not all potential contaminants have been analyzed. Further, information regarding possible future industrial practices at Canal Creek is lacking.	Qualitative, due to lack of information regarding future industrial processes that could occur at Canal Creek.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.

wells currently exist in the Canal Creek area, however. Although they have not been used in the recent past, they have not been permanently closed. Because of the existence of these wells and the historical use of groundwater in the area, ingestion of groundwater by workers under hypothetical future-use conditions was selected for evaluation. Such use is extremely unlikely, but this pathway was selected for quantitative evaluation as a means of evaluating groundwater in this area as a drinking water resource. Such an approach is consistent with EPA Region guidance for groundwater evaluations.[5] Workers were chosen as the potentially exposed population, even though people live in the Canal Creek study area, because workers are likely to have longer exposures (possibly up to 20 years) than the military families who are not likely to live at APG for more than 5 years.

Dermal contact and inhalation of volatile chemicals could also occur during use of groundwater as a tap water source. These are not likely to contribute significantly to ingestion exposures given that persons are not likely to bathe (for direct contact exposures) or shower (for inhalation exposures) at work. Therefore, these exposures are evaluated qualitatively.

Groundwater could also be used in small-scale manufacturing, which could take place in Canal Creek and at laboratories. If this were to occur, the most likely route of exposure would be inhalation of organic chemicals that have volatilized from water during industrial or laboratory practices. This pathway was qualitatively evaluated.

7.3.1.3 Quantification of Exposure

In this section, exposure estimates are presented for the pathways selected for quantitative evaluation. The only human exposure pathways selected for quantitative evaluation are:

- Current land-use. Chronic exposure of groundskeepers via dermal contact and incidental ingestion of chemicals in surface soil.
- Future land-use. Chronic exposure of workers via ingestion of groundwater from the surficial and Canal Creek aquifers and from the lower confined aquifer in the main industrial area of Canal Creek, and from the Canal Creek aquifer at the Salvage Yard.

The methods used to evaluate these exposures are described below.

7.3.1.3.1 Worker Exposures to Chemicals in Surface Soils

Table 7-16 presents the exposure point concentrations used to estimate chronic daily intakes for groundskeepers exposed to chemicals in surface soils via incidental ingestion and dermal absorption. The exposure point concentration is the lower value of the upper 95% confidence limit on the arithmetic mean or maximum detected value. Table 7-17 presents the other exposure parameters used to evaluate this pathway. These assumptions are discussed below.

To evaluate incidental ingestion exposures, in lieu of site-specific information on this activity, it was assumed that the workers perform work involving digging (e.g., planting shrubs, laying sod) at Canal Creek for 1 day per week from March through October, for a total of 32 days per year, for a period of

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[5] Davis, C. Personal communication. EPA Region 3. November 8, 1990.

TABLE 7-16

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE SOIL AT CANAL CREEK

(Concentrations reported in mg/kg)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
p,p'-DDE (PPDDE)	0.20	0.22	0.595	0.22
Di-n-butylphthalate (DNBP)	0.049	0.054	0.21	0.054
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	0.037	0.043	0.052	0.043
Trichlorofluoromethane (CCL3F)	0.0037	0.0039	0.028	0.0039
Inorganic Chemicals:				
Antimony (SB)	6.4	7.8	20.7	7.8
Arsenic (AS)	5.1	5.8	11	5.8
Chromium (CR)	29	37	139	37
Copper (CU)	50	52	104	52
Iron (FE)	13,000	17,000	54,000	17,000
Lead (PB)	130	560	1,100	560
Manganese (MN)	390	480	2,930	480
Mercury (HG)	0.1	0.1	0.9	0.1
Selenium (SE)	0.2	0.2	1.2	0.2
Zinc (ZN)	90	120	361	120

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

TABLE 7-17

PARAMETERS USED TO ESTIMATE EXPOSURES FOR DIRECT CONTACT WITH SURFACE SOILS BY GROUNDS MAINTENANCE WORKERS IN THE CANAL CREEK STUDY AREA

Parameter	Value
Exposure Frequency (a)	32 days/year
Exposure Duration (b)	20 years
Soil Ingestion Rate (c)	100 mg/day
Skin Surface Area (d)	200 cm2/day
Soil to Skin Adherence Factor (e)	2.11 mg/cm2
Body weight (f)	70 kg
Lifetime (g)	70 years
Relative Oral Absorption Fraction For Soil Matrix:	
Arsenic (h)	0.8
Di-n-butylphthalate (i)	0.5
Other chemicals of potential concern (j)	1.0
Dermal Absorption Fraction:	
p,p'-DDE (k)	0.02
Di-n-butylphthalate (l)	0.05
Other organics (l)	0.10
Inorganics (l)	0

(a) Based on one time per week from March through October.
(b) Based on the time a typical civilian worker spends working at APG.
(c) Based on age groups greater than 6 years old (EPA 1989a).
(d) EPA (1989b).
(e) Based on an average of the adherence factor of commercial potting soil and kaolin clay (EPA 1989a).
(f) EPA (1989b).
(g) Based on EPA (1989a) standard assumption for a lifetime.
(h) An oral absorption factor of 0.8 is used for arsenic because its oral potency factor is based on an absorbed dose.
(i) Based on data on 2,3,7,8-TCDD (Poiger and Schlatter 1980, Wendling et al. 1989, McConnell et al. 1984).
(j) Default value.
(k) Based on Poiger and Schlatter (1980).
(l) Estimated value based on analogy to other chemicals and physical chemical properties.

20 years employment at APG. Based on EPA recommendations 100 mg soil per day is assumed to be ingested by these workers during the course of their work (EPA 1989a). Standard assumptions for adult body weight of 70 kg (EPA 1989b) and a lifetime of 70 years (EPA 1989a) were used. Chronic exposures from incidental ingestion of soil were calculated using these assumptions and the following equation:

$$CDI = (C_s * IR * EF * ED * Z * Bio_s) / (BW * DY * YL) \quad \text{(Eq. 1)}$$

where:

CDI = chronic daily intake (mg/kg-day);

C_s = exposure point concentration in soil (mg/kg);

IR = ingestion rate (100 mg/day);

EF = exposure frequency (32 days/year);

ED = exposure duration (20 years);

Z = conversion factor (kg/10^6 mg);

Bio_s = bioavailability factor (unitless);

BW = body weight over the period of exposure (70 kg);

DY = days in a year (365 days/year); and

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure [20 years] for noncarcinogens) (years).

Bioavailability values are used when determining the amount of chemical that is absorbed in the gastrointestinal tract. Because of their affinity for soil particles, chemicals that are present in a soil matrix may not be as readily absorbed through the gut as chemicals ingested in a solution or diet (i.e., the matrices usually administered in experimental studies from which cancer slope factors and RfDs are derived). To account for the expected differences in oral absorption between the ingestion of chemicals adsorbed onto soil and the animal study conditions, a relative absorption factor was applied to the CDI calculations.

CDIs calculated using these exposure assumptions are presented in Table 7-18.

To estimate dermal exposures, the amount of adherence to the skin, the area of skin exposed, and the amount of contaminant absorption were determined. It is assumed that 200 cm^2 of skin is exposed, based on estimates of exposed surface area derived using data on the mean surface area of arms and forearms for adult males (EPA 1989b). The soil contact rate (in mg soil/day) was calculated by multiplying the soil adherence value of 2.11 mg/cm^2 (an average of the values for commercial potting soil and kaolin clay) by the assumed skin area exposed. The other exposure parameters are

TABLE 7-18

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL BY GROUNDS MAINTENANCE WORKERS AT CANAL CREEK (a)

Chemical (b)	RME Concentration (mg/kg)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
p,p'-DDE (PPDDE)	2.20E-01	7.9E-09
Arsenic (AS)	5.80E+00	1.7E-07
Chemicals Exhibiting Noncarcinogenic Effects		
Di-n-butylphthalate (DNBP)	5.40E-02	3.4E-09
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	4.30E-02	5.4E-09
Trichlorofluoromethane (CCL3F)	3.90E-03	4.9E-10
Antimony (SB)	7.80E+00	9.8E-07
Arsenic (AS)	5.80E+00	5.8E-07
Chromium (CR)	3.70E+01	4.6E-06
Copper (CU)	5.20E+01	6.5E-06
Manganese (MN)	4.80E+02	6.0E-05
Mercury (HG)	1.00E-01	1.3E-08
Selenium (SE)	2.00E-01	2.5E-08
Zinc (ZN)	1.20E+02	1.5E-05

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron and lead.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

the same as for the incidental ingestion exposures. Chronic dermal absorption exposures were calculated using these assumptions and the following equation:

$$CDI = (C_s * SA * AF * ABS * EF * ED * Z)/(BW * DY * YL) \qquad \text{(Eq. 2)}$$

where:

CDI = chronic daily intake (mg/kg-day);

C_s = exposure point concentration in soil (mg/kg);

SA = surface area (cm^2);

AF = adherence factor of soil to skin (2.11 mg/cm^2);

ABS = absorption factor (unitless);

EF = exposure frequency (32 days/year);

ED = exposure duration (20 years);

Z = conversion factor ($kg/10^6$ mg);

BW = body weight over the period of exposure (70 kg);

DY = days in a year (365 days/year); and

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure [20 years] for noncarcinogens) (years).

The absorption factor in the above equation is a chemical-specific number. Few data are available on the amount of chemicals absorbed from soil via the dermal route under conditions normally encountered in the environment. For the purposes of this assessment, the amount of exposure via dermal absorption was evaluated by estimating the absorption from contacted soil that may occur for each chemical of concern. For a chemical to be absorbed by the skin from soil, it must be released from the soil matrix, pass through the stratum corneum, the epidermis, the dermis, and into the systemic circulation. Where relevant experimental data were available, they were used to derive absorption factors. If too few data were available to support such estimates, default values were used. The available experimental data indicate that metals are poorly absorbed through intact skin during exposures of short duration (Lang and Kunze 1948; Skog and Wahlberg 1964; Wahlberg 1968).

CDIs for dermal absorption of chemicals, calculated using the above information, are presented in Table 7-19.

TABLE 7-19

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY GROUNDS MAINTENANCE WORKERS AT CANAL CREEK (a)

Chemical (b)	RME Concentration (mg/kg)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
p,p'-DDE (PPDDE)	2.20E-01	6.6E-10
Chemicals Exhibiting Noncarcinogenic Effects		
Di-n-butylphthalate (DNBP)	5.40E-02	1.4E-09
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	4.30E-02	2.3E-09
Trichlorofluoromethane (CCL3F)	3.90E-03	2.1E-10

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria and that are absorbed by the dermal route. Inorganic chemicals of potential concern are not presented since dermal absorption of metals is expected to be insignificant. See text.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

7.3.1.3.2 Ingestion of Groundwater by Workers in the Canal Creek Study Area

The exposure point concentrations for this pathway are presented in Table 7-20 for the surficial and Canal Creek aquifers, in Table 7-21 for the lower confined aquifer, and in Table 7-22 for the Salvage Yard. As described above, the exposure point concentration is the lower value of the upper 95% confidence limit on the arithmetic mean or the maximum detected value. To evaluate this pathway, it was assumed that a person who works in the Canal Creek area for 20 years ingests 1 liter of water each work day. Twenty years is chosen as an upperbound estimate of the amount of time a civilian worker may stay in the same job at APG. Workers are assumed to work a total of 241 days each year for 20 years. This assumes a person works 5 days each week and takes 2 weeks vacation and 9 holidays each year. Standard assumptions of an adult body weight of 70 kg (EPA 1989b) and a lifetime of 70 years (EPA 1989a) were used. Drinking water exposures were calculated using these assumptions and the following equation:

$$CDI = (C_w * IR * EF * ED * Z) / (BW * DY * YL) \qquad \text{(Eq. 3)}$$

where:

CDI = chronic daily intake (mg/kg-day);

C_w = exposure point concentration in groundwater (µg/L);

IR = ingestion rate (1 liter/day);

EF = exposure frequency (241 days/year);

ED = exposure duration (20 years);

Z = conversion factor (mg/1,000 ug);

BW = body weight over the period of exposure (70 kg);

DY = days in a year (365 days/year); and

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure [20 years] for noncarcinogens) (years).

CDIs calculated using these exposure assumptions are presented in Tables 7-23 to 7-25.

7.3.2 TOXICITY ASSESSMENT

The description in Chapter 4 of the general methodology for the classification of health effects and the development of health effects criteria provides the analytical framework for the characterization of human health impacts. The health effects criteria that were used to derive estimates of risk for the pathways that are quantitatively evaluated in this health risk assessment (i.e., groundskeepers who incidentally ingest and dermally absorb chemicals in soil, and future workers ingesting groundwater) are presented in Table 7-26. Toxicity summaries for all chemicals of potential concern for the two

TABLE 7-20

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
ORGANIC CHEMICALS:				
Alkyl aromatics:				
Benzene (C6H6)	5.5	8.1 (d)	92.0	8.1
Ethyl Benzene (ETC6H5)	3.0	3.7	5.8	3.7
Halogenated aromatics:				
4-Bromofluorobenzene (4BFB)	130	160	160	160
Chlorobenzene (CLC6H5)	3.0	3.2	50.4	3.2
Cyclic sulfur compounds:				
Dithiane (DITH)	4.7	5.3	7.0	5.3
1,4-Oxathiane (OXAT)	6.5	7.8	19.8	7.8
Ethers:				
bis(2-Chloroethyl)ether (B2CLEE)	6.1	6.2	7.1	6.2
Halogenated alkanes:				
Carbon Tetrachloride (CCL4)	200	210	8,730	210
Chloroform (CHCL3)	30	45	565	45
1,2-Dichloroethane (12DCLE)	8.7	14 (d)	283	14
Methylene Chloride (CH2CL2)	6.3	6.8	50.4	6.8
1,1,2,2-Tetrachloroethane (TCLEA)	170	410	4,026	410
1,1,2-Trichloroethane (112TCE)	4.7	5.6	31.1	5.6
Halogenated alkenes:				
cis-1,2-Dichloroethene (C12DCE)	200	790	2,500	790
trans-1,2-Dichloroethene (T12DCE)	47	44	1,090	44
Tetrachloroethene (TCLEE)	6.8	9.8 (d)	110	9.8
Trichloroethene (TRCLE)	71	190	537	190
Vinyl Chloride (C2H3CL)	8.1	12 (d)	139	12
Nitro aromatics:				
Nitrobenzene (NB)	16	23	111	23
Phthalates:				
Bis(2-Ethylhexyl)phthalate (B2EHP)	18	32	30.0	30.0
Butylbenzylphthalate (BBZP)	12	15	100	15

See footnotes on the following page.

TABLE 7-20 (Continued)

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
INORGANIC CHEMICALS:				
Aluminum (AL)	840	1,500 (d)	21,500	1,500
Ammonia (NH3)	250	250	5,600	250
Antimony (SB)	2.5	2.7	12.0	2.7
Arsenic (AS)	3.5	3.5	45.0	3.5
Barium (BA)	66	87	278	87
Boron (B)	130	150	1,480	150
Cadmium (CD)	2.4	2.7	17.0	2.7
Chromium (CR)	10	19	20.1	19
Copper (CU)	15	22	169	22
Fluoride (F)	350	410	4,480	410
Iron (FE)	5,300	36,000	51,000	36,000
Lead (PB)	5.8	6.1	65.5	6.1
Manganese (MN)	840	2,400	24,500	2,400
Mercury (HG)	0.3	0.4	1.2	0.4
Nickel (NI)	29	44	214	44
Nitrite (NO2)	25	29	170	29
Nitrite/Nitrate (NIT)	480	750	3,200	750
Sulfate (SO4)	38,000	92,000	183,000	92,000
Sulfide (SULFID)	820	970	3,400	970
Zinc (ZN)	180	200	3,390	200

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution, except as noted.
(c) Value listed is the lower of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Value reflects a normal distribution.

TABLE 7-21

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CANAL CREEK LOWER CONFINED AQUIFER

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Inorganic Chemicals:				
Ammonia (NH3)	160	270	400	270
Chromium (CR)	3.5	6.7	10.0	6.7
Fluoride (F)	530	1,200	1,300	1,200
Iron (FE)	2,300	480,000	7,900	7,900
Manganese (MN)	62	2,000	210	210
Mercury (HG)	0.4	0.9	2.7	0.9
Nitrite (NO2)	24	55	50	50
Sulfate (SO4)	12,000	20,000	36,000	20,000
Sulfide (SULFID)	590	740	1,200	740
Zinc (ZN)	85	370	390	370

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

TABLE 7-22

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CANAL CREEK SALVAGE YARD

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Bis(2-ethylhexyl)phthalate (B2EHP)	NA	NA	1,000	1,000
Chloroform (CHCL3)	2.6	3.9	4.0	3.9
1,1-Dichloroethene (11DCE)	1.6	3.0	2.8	2.8
trans-1,2-Dichloroethene (T12DCE)	28	39,000	161	161
Di-n-octylphthalate (DNOP)	NA	NA	73	73
Methylene Chloride (CH2CL2)	11.0	55	28	28
1,1,2,2-Tetrachloroethane (TCLEA)	490	1.4E+10	2,940	2,940
1,1,2-Trichloroethane (112TCE)	8.3	550	43.5	43.5
Trichloroethene (TRCLE)	83	110,000,000	450	450
Inorganic Chemicals:				
Ammonia (NH3)	180	330	380	330
Beryllium (BE)	0.9	1.8	4.0	1.8
Boron (B)	69	130	110	110
Chromium (CR)	24	68	89	68
Copper (CU)	26	53	80	53
Fluoride (F)	240	390	630	390
Iron (FE)	150	1,600	810	810
Manganese (MN)	170	35,000	370	370
Nickel (NI)	96	2,600	610	610
Nitrite (NO2)	92	310	480	310
Nitrite/Nitrate (NIT) (d)	390	2,500	830	830
Selenium (SE)	2.2	4.7	5.0	4.7
Sulfate (SO4)	68,000	11,000,000	200,000	200,000
Zinc (ZN)	200	46,000	1,000	1,000

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Concentrations are reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

NA = Not applicable. Only one sample was collected.

TABLE 7-23

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR FUTURE INGESTION OF GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Benzene (C6H6)	8.1	2.2E-05
Carbon Tetrachloride (CCL4)	210	5.7E-04
bis(2-Chloroethyl)ether (B2CLEE)	6.2	1.7E-05
Chloroform (CHCL3)	45	1.2E-04
1,2-Dichloroethane (12DCLE)	14	3.8E-05
bis(2-Ethylhexyl)phthalate (B2EHP)	30.0	8.1E-05
Methylene Chloride (CH2CL2)	6.8	1.8E-05
1,1,2,2-Tetrachloroethane (TCLEA)	410	1.1E-03
Tetrachloroethene (TCLEE)	9.8	2.6E-05
1,2,2-Trichloroethane (112TCE)	5.6	1.5E-05
Trichloroethene (TRCLE)	190	5.1E-04
Vinyl Chloride (C2H3CL)	12	3.2E-05
Arsenic (AS)	3.5	9.4E-06
Chemicals Exhibiting Noncarcinogenic Effects		
Butylbenzylphthalate (BBZP)	15	1.4E-04
Carbon Tetrachloride (CCL4)	210	2.0E-03
Chlorobenzene (CLC6H5)	3.2	3.0E-05
Chloroform (CHCL3)	45	4.2E-04
cis-1,2-Dichloroethene (C12DCE)	790	7.5E-03
trans-1,2-Dichloroethene (T12DCE)	44	4.2E-04
Dithiane (DITH)	5.3	5.0E-05
Ethyl Benzene (ETC6H5)	3.7	3.5E-05
bis(2-Ethylhexyl)phthalate (B2EHP)	30.0	2.8E-04
Methylene Chloride (CH2CL2)	6.8	6.4E-05
Nitrobenzene (NB)	23	2.2E-04
1,1,2,2-Tetrachloroethane (TCLEA)	410	3.9E-03
Tetrachloroethene (TCLEE)	9.8	9.2E-05
1,2,2-Trichloroethane (112TCE)	5.6	5.3E-05
Trichloroethene (TRCLE)	190	1.8E-03
Ammonia (NH3)	250	2.4E-03
Antimony (SB)	2.7	2.5E-05
Arsenic (AS)	3.5	3.3E-05
Barium (BA)	87	8.2E-04
Boron (B)	150	1.4E-03
Cadmium (CD)	2.7	2.5E-05
Chromium (CR)	19	1.8E-04
Copper (CU)	22	2.1E-04
Fluoride (F)	410	3.9E-03
Manganese (MN)	2,400	2.3E-02
Mercury (HG)	0.4	3.8E-06
Nickel (NI)	44	4.2E-04
Nitrite (NO2)	29	2.7E-04
Nitrite/Nitrate (NIT) (d)	750	7.1E-03
Zinc (ZN)	200	1.9E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 4-bromofluorobenzene, 1,4-oxathiane, aluminum, iron, lead, sulfate, and sulfide.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

(d) Concentrations are reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

TABLE 7-24

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR FUTURE INGESTION OF GROUNDWATER AT CANAL CREEK LOWER CONFINED AQUIFER (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Noncarcinogenic Effects		
Ammonia (NH3)	270	2.5E-03
Chromium (CR)	6.7	6.3E-05
Fluoride (F)	1,200	1.1E-02
Manganese (MN)	210	2.0E-03
Mercury (HG)	0.9	8.5E-06
Nitrite (NO2)	50	4.7E-04
Zinc (ZN)	370	3.5E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron, sulfate, and sulfide.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

TABLE 7-25

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR FUTURE INGESTION OF GROUNDWATER AT CANAL CREEK SALVAGE YARD (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Chloroform (CHCL3)	3.9	1.1E-05
1,1-Dichloroethene (11DCE)	2.8	7.5E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	1,000	2.7E-03
Methylene Chloride (CH2CL2)	28	7.5E-05
1,1,2,2-Tetrachloroethane (TCLEA)	2,940	7.9E-03
1,1,2-Trichloroethane (12TCE)	43.5	1.2E-04
Trichloroethene (TRCLE)	450	1.2E-03
Beryllium (BE)	1.8	4.9E-06
Chemicals Exhibiting Noncarcinogenic Effects		
Chloroform (CHCL3)	3.9	3.7E-05
1,1-Dichloroethene (11DCE)	2.8	2.6E-05
trans-1,2-Dichloroethene (T12DCE)	161	1.5E-03
Di-n-octylphthalate (DNOP)	73	6.9E-04
bis(2-Ethylhexyl)phthalate (B2EHP)	1,000	9.4E-03
Methylene Chloride (CH2CL2)	28	2.6E-04
1,1,2,2-Tetrachloroethane (TCLEA)	2,940	2.8E-02
1,1,2-Trichloroethane (12TCE)	43.5	4.1E-04
Trichloroethene (TRCLE)	450	4.2E-03
Ammonia (NH3)	330	3.1E-03
Beryllium (BE)	1.8	1.7E-05
Boron (B)	110	1.0E-03
Chromium (CR)	68	6.4E-04
Copper (CU)	53	5.0E-04
Fluoride (F)	390	3.7E-03
Manganese (MN)	370	3.5E-03
Nickel (NI)	610	5.8E-03
Nitrite (NO2)	310	2.9E-03
Nitrite/Nitrate (NIT) (d)	830	7.8E-03
Selenium (SE)	4.7	4.4E-05
Zinc (ZN)	1,000	9.4E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron and sulfate.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

(d) Concentrations are reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

TABLE 7-26

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN
AT CANAL CREEK

Chemical	Chronic Reference Dose (mg/kg/day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg/day)-1	EPA Weight of Evidence Classification (c)	Slope Factor Source
Organic Chemicals:							
Benzene	--	--	--	IRIS	2.90E-02	A	IRIS
4-Bromofluorobenzene	--	--	--	--	--	--	--
Butylbenzylphthalate	2.00E-01	1,000	Testes/Liver/	IRIS	--	C	IRIS
Carbon Tetrachloride	7.00E-04	1,000	Liver	IRIS	1.30E-01	B2	IRIS
Chlorobenzene	2.00E-02	1,000	Kidney/Liver	IRIS	--	--	IRIS
bis(2-Chloroethyl)ether	--	--	--	IRIS	1.10E+00	B2	IRIS
Chloroform	1.00E-02	1,000	Liver	IRIS	6.10E-03	B2	IRIS
4,4'-DDE	--	--	--	IRIS	3.40E-01	B2	IRIS
Di-n-butylphthalate	1.00E-01	1,000	Mortality	IRIS	--	--	IRIS
1,2-Dichloroethane	--	--	--	IRIS	9.10E-02	B2	IRIS
1,1-Dichloroethene	9.00E-03	1,000	Liver	IRIS	6.00E-01	C	IRIS
cis-1,2-Dichloroethene	1.00E-02	3,000	Blood	HEAST	--	--	--
trans-1,2-Dichloroethene	2.00E-02	1,000	Blood	IRIS	--	--	--
Dithiane	1.00E-01	1,000	Nasal epithelium	CLEMENT	--	--	--
Di-n-octylphthalate	2.00E-02	1,000	Liver/Kidney	HEAST	--	--	HEAST
Ethyl Benzene	1.00E-01	1,000	Liver/Kidney	IRIS	--	D	IRIS
bis(2-Ethylhexyl)phthalate	2.00E-02	1,000	Liver	IRIS	1.40E-02	B2	IRIS
Methylene Chloride	6.00E-02	100	Liver	IRIS	7.50E-03	B2	IRIS
Nitrobenzene	5.00E-04	10,000	Kidney/Liver	IRIS	--	D	IRIS
1,4-Oxathiane	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	4.60E-04	1,000	Liver/White Blood Cells	(d)	2.00E-01	C	IRIS
1,1,2-Trichloroethane	4.00E-03	1,000	Clinical chem.	IRIS	5.70E-02	C	IRIS
Tetrachloroethene	1.00E-02	1,000	Liver	IRIS	5.10E-02	B2	HEAST
Trichloroethene	7.35E-03	1,000	Liver	HA	1.10E-02	B2	HEAST
Trichlorofluoromethane	3.00E-01	1,000	Mortality	IRIS	--	--	--
1,1,2-Trichloro-1,2,2-trifluoroethane	3.00E+01	10	CNS	IRIS	--	--	IRI
Vinyl Chloride	--	--	--	--	2.30E+00	A	HEAS
Inorganic Chemicals:							
Aluminum	--	--	--	--	--	--	--
Ammonia	3.40E+01 mg/l	--	(e)	HEAST	--	--	--
Ammonia Nitrogen	--	--	--	--	--	--	--
Antimony	4.00E-04	1,000	Blood	IRIS	--		IRIS
Arsenic	1.00E-03	1	Skin	HEAST	2.00E+00 (f)	A	IRIS
Barium	7.00E-02	3	Cardiovascular System	IRIS	--	--	IRIS
Beryllium	5.00E-03	100	Various Organs (Tumors)	IRIS	4.3E+00	B2	--
Boron	9.00E-02	100	Testes	IRIS	--	--	--
Cadmium	5.00E-04	10	Kidney	IRIS	--	--	IRIS
Chromium III and compounds	1.00E+00	1,000	Liver	IRIS	--	--	--
Chromium VI and compounds	5.00E-03	500	CNS	IRIS	--	--	IRIS
Copper	3.71E-02 (g)	1	Gastrointestinal Tract	HEAST	--	D	IRIS
Fluoride	6.00E-02	1	Teeth	HEAST	--	--	--
Iron	--	--	--	HEAST	--	--	--
Lead	--	--	--	IRIS	--	B2	IRIS
Manganese	1.00E-01	1	CNS	IRIS	--	--	--
Mercury, inorganic	3.00E-04	1,000	Kidney	HEAST	--	D	IRIS
Nickel	2.00E-02	300	Body weight	IRIS	--	--	IRIS
Nitrate	--	--	--	IRIS	--	--	IRIS
Nitrite	1.00E-01	10	Blood	IRIS	--	--	IRIS
Selenious Acid/Selenium	3.00E-03	15	Skin	IRIS	--	--	IRIS
Sulfate	--	--	--	--	--	--	--
Sulfide	--	--	--	--	--	--	--
Zinc	2.00E-01	10	Blood (Anemia)	HEAST	--	--	HEAST

See footnotes on the following page.

TABLE 7-26 (Continued)

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT CANAL CREEK

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

(d) Interim RfD approved by ECAO, Cincinnati.

(e) The RfD for ammonia is based on a taste threshold rather than on a health effect.

(f) EPA 1988. Special report on ingested inorganic arsenic skin cancer; nutritional essentiality. Risk assessment forum. EPA, Washington, D.C. EPA/625/3-87/013F. July 1988.

(g) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.

NOTE: IRIS = Integrated Risk Information System - December 1, 1990.
HA = Health Advisory.
HEAST = Health Effects Assessment Summary Tables - July 1, 1990.
-- = No information available.

pathways, as well as the toxicological basis of the health effects criteria presented in Table 7-26, are provided in Appendix B.

No EPA-approved oral toxicity criteria are available for aluminum, ammonia, nitrogen, iron, lead, sulfate, sulfide, 1,4-oxathiane, and 4-bromofluorobenzene. Therefore, potential risks associated with exposure to these chemicals were not quantitatively evaluated. The potential contribution of these chemicals to the overall estimates of risk for incidental ingestion by workers is discussed qualitatively in the risk characterization section.

No toxicity criteria are provided in Table 7-26 for the other chemicals being qualitatively evaluated in this risk assessment. Toxicity summaries for these chemicals are provided in Appendix B.

7.3.3 RISK CHARACTERIZATION

In this section, the human health risks potentially associated with the Canal Creek study area are evaluated. Risks are evaluated either quantitatively or qualitatively. Potential risks under current land-use conditions are presented in Section 7.2.3.1 and those under hypothetical future land-use conditions are presented in Section 7.2.3.2.

7.3.3.1 Potential Risks Under Current Land-Use Conditions

The exposure pathways selected for evaluation under current land-use conditions are:

- Chronic exposure of groundskeepers via incidental ingestion and dermal absorption of chemicals in surface soil;
- Chronic inhalation exposure of persons living and working in the Canal Creek area to chemicals that have volatilized from surface water and from the subsurface environment (from groundwater, soils, or wastes);
- Chronic or subchronic exposure of people who ingest game that has accumulated chemicals from the Canal Creek study area; and
- Acute inhalation and dermal exposure of workers encountering agent-containing munitions, bulk chemical agents, and unexploded ordnance during excavation or similar activities.

Chronic soil exposure in workers was evaluated quantitatively. The other three exposure pathways were evaluated qualitatively. The potential risks associated with each of these pathways are discussed below.

7.3.3.1.1 Risks to Groundskeepers Exposed to Chemicals in Surface Soils

Table 7-27 presents the estimated cancer risks and noncarcinogenic hazards associated with incidental ingestion of chemicals in soil by groundskeepers. The upper-bound excess lifetime cancer risk for this pathway is 3×10^{-7}, primarily due to arsenic. The Hazard Index for incidental ingestion of chemicals in soil is less than 1.

TABLE 7-27

POTENTIAL RISKS ASSOCIATED WITH INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL BY GROUNDS MAINTENANCE WORKERS AT CANAL CREEK (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
p,p'-DDE (PPDDE)	7.9E-09	3.4E-01	B2	3E-09
Arsenic (AS)	1.7E-07	2.0E+00	A	3E-07
TOTAL	--	--	--	3E-07

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Di-n-butylphthalate (DNBP)	3.4E-09	1.0E-01	1,000	Mortality	3E-08
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	5.4E-09	3.0E+01	10	CNS	2E-10
Trichlorofluoromethane (CCL3F)	4.9E-10	3.0E-01	1,000	Mortality	2E-09
Antimony (SB)	9.8E-07	4.0E-04	1,000	Blood	2E-03
Arsenic (AS)	5.8E-07	1.0E-03	1	Skin	6E-04
Chromium (CR)	4.6E-06	5.0E-03 (f)	500	CNS	9E-04
Copper (CU)	6.5E-06	3.71E-02 (g)	1	GI Tract	2E-04
Manganese (MN)	6.0E-05	1.0E-01	1	CNS	6E-04
Mercury (HG)	1.3E-08	3.0E-04	1,000	Kidney	4E-05
Selenium (SE)	2.5E-08	3.0E-03	15	Skin	8E-06
Zinc (ZN)	1.5E-05	2.0E-01	10	Blood (Anemia)	8E-05
HAZARD INDEX	--	--	--	--	< 1 (5E-03)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron and lead.

(b) USATHAMA chemical codes listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies; and
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

(f) The RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.

(g) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.

Table 7-28 presents the estimated carcinogenic risks and noncarcinogenic hazards associated with dermal absorption of chemicals in soil by groundskeepers. The upper-bound excess lifetime cancer risk for this pathway is $2x10^{-10}$ due to p,p'-DDE, the only carcinogen that was evaluated for this pathway. (As noted earlier, exposures to metals via the dermal absorption route are insignificant, and therefore were not evaluated). The Hazard Index for dermal absorption of chemicals in soil under the RME exposure case is less than 1.

The total risk to grounds maintenance workers is the sum of the risks for incidental ingestion and dermal absorption. The total excess lifetime cancer risk for this pathway is thus $3x10^{-7}$. This value is below the $1x10^{-6}$ risk level often used as a benchmark by regulatory agencies in determining the need for corrective action at a hazardous waste site. The total Hazard Index for this pathway is less than 1.

This evaluation of risks did not include iron and lead, as these chemicals do not have established toxicity criteria. Although the oral toxicity of iron has not been well described, the limited toxicity information that is available suggests that this essential nutrient is significantly less toxic than the other chemicals of potential concern for which health effects criteria are available. Lead is known to be very toxic and could theoretically contribute significantly to estimates of risk. In the absence of established toxicity criteria, the potential risks associated with exposure to lead in soils can be evaluated by comparing the lead concentration in Canal Creek surface soils with guidance values for the protection of human health. EPA (1989c) has recommended that lead concentrations in soils at Superfund sites be in the range of 500 to 1,000 mg/kg for residential use areas, which is the land use associated with the greatest potential for significant exposures. The RME concentration of lead in the surface soils of the Canal Creek study area is 560 mg/kg. This value is in the low end of the protective range. Because exposures in grounds maintenance workers will be significantly less than in residential users (for which the standard was derived), lead in Canal Creek soils is not likely to pose a human health problem.

7.3.3.1.2 Chronic Inhalation Exposures in the Canal Creek Study Area

Persons living and working in the Canal Creek study area could be exposed to chemicals volatilized from surface water that has received groundwater discharge and from subsurface wastes, soils, or groundwater. No air samples have been collected in the Canal Creek study area, and the data that are available are not sufficient to model air emissions from direct discharge of volatiles to surface water or volatilization and transport through soil. Therefore, this pathway was not quantitatively evaluated. Judging by the number and type of chemicals present in groundwater in the Canal Creek study area, however, significant inhalation exposures and risks are possible. Several of the volatile chemicals detected in the surficial and Canal Creek aquifers are known or suspected human carcinogens (e.g., benzene, vinyl chloride, carbon tetrachloride, tetrachloroethene, and trichloroethene) and still others are possible human carcinogens (e.g., 1,1,2,2-tetrachloroethane and 1,1,-dichloroethene). Depending upon their cancer potency, many of these potential carcinogens can be associated with estimates of excess lifetime cancer risks even at relatively low exposure concentrations in ambient air. Many of these potential carcinogens, along with the other volatile chemicals in groundwater, have also been associated with noncarcinogenic health effects. Given the large number of these volatile chemicals in groundwater, cumulative exposures to all the noncarcinogens could result in noncarcinogenic health hazards.

TABLE 7-28

POTENTIAL RISKS ASSOCIATED WITH DERMAL ABSORPTION OF CHEMICALS IN SURFACE SOIL BY GROUNDS MAINTENANCE WORKERS AT CANAL CREEK (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (c) (mg/kg-day)-1	Weight of Evidence Class (d)	Upper Bound Excess Lifetime Cancer Risk
p,p'-DDE (PPDDE)	6.6E-10	3.4E-01	B2	2E-10
TOTAL	--	--	--	2E-10

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (c) (mg/kg-day)	Uncertainty Factor (e)	Target Organ (f)	CDI:RfD Ratio
Di-n-butylphthalate (DNBP)	1.4E-09	1.0E-01	1,000	Mortality	1E-08
1,1,2-Trichloro-1,2,2-trifluoroethane (TCLTFE)	2.3E-09	3.0E+01	10	CNS	8E-11
Trichlorofluoromethane (CCL3F)	2.1E-10	3.0E-01	1,000	Mortality	7E-10
HAZARD INDEX	--	--	--	--	< 1 (2E-08)

(a) Risks are calculated only for chemicals with toxicity criteria and that are absorbed by the dermal route. None of the inorganic chemicals of potential concern are presented, since dermal absorption of metals is expected to be insignificant.
(b) USATHAMA chemical codes listed in parentheses.
(c) Oral toxicity values are used in dermal absorption pathways.
(d) EPA Weight of Evidence for Carcinogenic Effects: [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.
(e) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(f) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(g) The RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(h) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.

7.3.3.1.3 Chronic or Subchronic Exposures in Persons Ingesting Game That Has Accumulated Chemicals from the Canal Creek Study Area

People could be exposed to chemicals of potential concern that have accumulated in game living in the Canal Creek study area. Game could be exposed to chemicals via ingestion of surface water, ingestion of food that has accumulated chemicals, or ingestion of sediment or soil while foraging or grooming. Several of the chemicals detected in the Canal Creek study area (e.g., PCBs, DDT) could accumulate in terrestrial game species and are potentially very toxic to humans. However, potential accumulation of these chemicals in terrestrial game species cannot be evaluated because of a lack of information on the type, magnitude, and extent of contamination in the Canal Creek study area. Potentially significant accumulation could result if large portions of the watershed were contaminated with chemicals that could potentially bioaccumulate in game species. The potential significance of this pathway was not evaluated due to limited sampling information in areas where game are expected to forage.

7.3.3.1.4 Acute Hazards

In addition to the chronic exposure of workers at Canal Creek described above, maintenance workers could be exposed to acute hazards if they unearth unexploded ordnance or large quantities of chemicals disposed of in the past. No data are available with which to predict the magnitude of potential direct contact exposures to chemicals in the subsurface soils at Canal Creek, because the necessary sampling has not been conducted. However, given the past disposal activities at Canal Creek, significant subsurface contamination is likely. A variety of chemicals could still be present in the various disposal pits, including:

- Some moderately persistent lethal agents: mustard could still be present if containerized; lewisite could still be present if protected from degradation processes; and tabun could be present in undecontaminated laboratory items.
- Persistent incapacitating agents: adamsite has a low mobility and high persistence in soils as a result of a protective film of adamsite oxide on the surface of solid adamsite; and chloroacetophenone is persistent due to its low volatility, solubility, and hydrolysis rate.
- Smoke/incendiary materials: white phosphorus, which was disposed of in great quantities, is still known to be present.

The concentrations of some of these chemicals in the waste disposal pits and underlying soils are likely to be high, because of the quantities that were disposed of in the past, as well as the environmental persistence of many of the chemicals in the form in which they were disposed of. Some chemicals (i.e., white phosphorus) have been uncovered in the past during sewer maintenance work, and are thus known to be present. As a result, the potential exists for significant exposures if these wastes are encountered. The chemicals potentially present in the disposal pits have a variety of toxic effects, ranging from lethality (e.g., mustard) to incapacitation (e.g., adamsite). Because of the potentially high concentrations in the disposal areas and the severe nature of possible toxic effects, direct contact exposures with chemicals could result in significant health risks to exposed individuals. However, due to the strict protocol required by the Safety Office when "breaking ground," such acute exposures are unlikely to occur.

7.3.3.2 Potential Risks Under Future Land-Use Conditions

The exposure pathways selected for evaluation under the hypothetical future land-use conditions are:

- Worker ingestion, dermal contact, and inhalation of chemicals in untreated groundwater from the surficial and Canal Creek aquifers, the lower confined aquifer, and the Salvage Yard groundwater; and

- Worker inhalation exposures to volatile organic chemicals present in untreated groundwater used for industrial purposes.

Drinking water exposures were evaluated quantitatively, and inhalation exposures were evaluated qualitatively. Potential risks are discussed below.

7.3.3.2.1 Ingestion of Groundwater by Workers

Table 7-29 presents the estimated carcinogenic risks and noncarcinogenic hazards associated with worker ingestion of groundwater from the Canal Creek and surficial aquifers in the main industrial area of the Canal Creek area. The upper-bound excess lifetime cancer risk for this pathway is $4x10^{-4}$. This value is above the risk level of $1x10^{-6}$ often used by regulatory agencies in determining the need for corrective action at hazardous waste sites. The estimated excess cancer risks are due primarily to 1,1,2,2-tetrachloroethane, carbon tetrachloride, and vinyl chloride. 1,1,2,2-Tetrachloroethane is a class C carcinogen (possible carcinogen) based on limited evidence of carcinogenicity from animal studies. Therefore, estimates of excess lifetime cancer risks associated with this chemical are uncertain. The other chemicals driving risk are class A (known human carcinogen; vinyl chloride) and class B2 (probable human carcinogen; carbon tetrachloride). The Hazard Index for ingestion of groundwater from these two aquifers by future workers is greater than one. When the chemicals of potential concern are grouped with respect to target organ toxicity, the Hazard Index exceeds 1 for liver toxicants, primarily due to 1,1,2,2-tetrachloroethane and carbon tetrachloride, which each have CDI:RfD ratios greater than 1. None of the other target organ chemical groups have Hazard Indices greater than 1.

Table 7-30 presents the estimated noncarcinogenic hazards associated with ingestion of groundwater from the lower confined aquifer by future workers. (No carcinogens were selected as chemicals of potential concern for this aquifer.) The Hazard Index for ingestion of groundwater from this aquifer by future workers is less than 1, indicating that no adverse effects are likely to occur from ingestion of this water.

Table 7-31 presents the estimated carcinogenic risks and noncarcinogenic hazards associated with ingestion of groundwater from the Canal Creek aquifer at the Salvage Yard by future workers. The upper-bound excess lifetime cancer risk for this pathway is $2x10^{-3}$. This value is above the risk level of $1x10^{-6}$ often used by regulatory agencies in determining the need for corrective action at hazardous wastes sites and is due primarily to 1,1,2,2-tetrachloroethane (a class C carcinogen). The Hazard Index for ingestion of groundwater from the Salvage Yard by future workers is greater than 1. When the chemicals of potential concern are grouped with respect to target organ toxicity, the Hazard Index exceeds 1 for liver toxicants, due principally to 1,1,2,2-tetrachloroethane, which has a CDI:RfD ratio greater than 1. None of the other target organ chemical groups have Hazard Indices greater than 1.

TABLE 7-29

POTENTIAL RISKS ASSOCIATED WITH FUTURE INGESTION OF GROUNDWATER AT CANAL CREEK SURFICIAL AND CANAL CREEK AQUIFERS (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Benzene (C6H6)	2.2E-05	2.9E-02	A	6E-07
Carbon Tetrachloride (CCL4)	5.7E-04	1.3E-01	B2	7E-05
bis(2-Chloroethyl)ether (B2CLEE)	1.7E-05	1.1E+00	B2	2E-05
Chloroform (CHCL3)	1.2E-04	6.1E-03	B2	7E-07
1,2-Dichloroethane (12DCLE)	3.8E-05	9.1E-02	B2	3E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	8.1E-05	1.4E-02	B2	1E-06
Methylene Chloride (CH2CL2)	1.8E-05	7.5E-03	B2	1E-07
1,1,2,2-Tetrachloroethane (TCLEA)	1.1E-03	2.0E-01	C	2E-04
Tetrachloroethene (TCLEE)	2.6E-05	5.1E-02	B2	1E-06
1,2,2-Trichloroethane (112TCE)	1.5E-05	5.7E-02	C	9E-07
Trichloroethene (TRCLE)	5.1E-04	1.1E-02	B2	6E-06
Vinyl Chloride (C2H3CL)	3.2E-05	2.3E+00	A	7E-05
Arsenic (AS)	9.4E-06	2.0E+00 (d)	A	2E-05
TOTAL	--	--	--	4E-04

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (e)	Target Organ (f)	CDI:RfD Ratio
Butylbenzylphthalate (BBZP)	1.4E-04	2.0E-01	1,000	Testes/Liver/Kidney	7E-04
Carbon Tetrachloride (CCL4)	2.0E-03	7.0E-04	1,000	Liver	3E+00
Chlorobenzene (CLC6H5)	3.0E-05	2.0E-02	1,000	Kidney/Liver	2E-03
Chloroform (CHCL3)	4.2E-04	1.0E-02	1,000	Liver	4E-02
cis-1,2-Dichloroethene (C12DCE)	7.5E-03	1.0E-02	3,000	Blood	7E-01
trans-1,2-Dichloroethene (T12DCE)	4.2E-04	2.0E-02	1,000	Blood	2E-02
Dithiane (DITH)	5.0E-05	1.0E-01	1,000	Nasal epithelium	5E-04
Ethyl Benzene (ETC6H5)	3.5E-05	1.0E-01	1,000	Liver/Kidney	3E-04
bis(2-Ethylhexyl)phthalate (B2EHP)	2.8E-04	2.0E-02	1,000	Liver	1E-02
Methylene Chloride (CH2CL2)	6.4E-05	6.0E-02	100	Liver	1E-03
Nitrobenzene (NB)	2.2E-04	5.0E-04	10,000	Kidney/Liver	4E-01
1,1,2,2-Tetrachloroethane (TCLEA)	3.9E-03	4.6E-04	1,000	Liver/WBC	8E+00
Tetrachloroethene (TCLEE)	9.2E-05	1.0E-02	1,000	Liver	9E-03
1,2,2-Trichloroethane (112TCE)	5.3E-05	4.0E-03	1,000	Clinical chem.	1E-02
Trichloroethene (TRCLE)	1.8E-03	7.35E-03	1,000	Liver	2E-01
Ammonia (NH3)	2.4E-03	9.71E-01 (g)	--	--	2E-03
Antimony (SB)	2.5E-05	4.0E-04	1,000	Blood	6E-02
Arsenic (AS)	3.3E-05	1.0E-03	1	Skin	3E-02
Barium (BA)	8.2E-04	7.0E-02	3	Cardiovasc. Sys.	1E-02
Boron (B)	1.4E-03	9.0E-02	100	Testes	2E-02
Cadmium (CD)	2.5E-05	5.0E-04	10	Kidney	5E-02
Chromium (CR)	1.8E-04	5.0E-03 (h)	500	CNS	4E-02
Copper (CU)	2.1E-04	3.71E-02 (i)	1	GI Tract	6E-03
Fluoride (F)	3.9E-03	6.0E-02	1	Teeth	6E-02
Manganese (MN)	2.3E-02	1.0E-01	1	CNS	2E-01
Mercury (HG)	3.8E-06	3.0E-04	1,000	Kidney	1E-02
Nickel (NI)	4.2E-04	2.0E-02	300	Body weight	2E-02
Nitrite (NO2)	2.7E-04	1.0E-01	10	Blood	3E-03
Nitrite/Nitrate (NIT)	7.1E-03	1.0E-01 (j)	10	Blood	7E-02
Zinc (ZN)	1.9E-03	2.0E-01	10	Blood (Anemia)	9E-03
HAZARD INDEX	--	--	--	--	> 1 (1E+01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: 4-bromofluorobenzene, 1,4-oxathiane, aluminum, iron, lead, sulfate, and sulfide.

(b) USATHAMA chemical codes listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects:

[A] = Human carcinogen based on adequate evidence from human studies;

[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and

[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(e) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(f) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

(g) The RfD for ammonia, based on a taste threshold, was converted from mg/L to mg/kg-day by assuming that a 70 kg adult drinks 2 liters of water per day.

(h) The RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.

(i) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.

(j) The RfD for nitrate is used for nitrite/nitrate (NIT).

TABLE 7-30

POTENTIAL RISKS ASSOCIATED WITH FUTURE INGESTION OF GROUNDWATER AT CANAL CREEK LOWER CONFINED AQUIFER (a)

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (c)	Target Organ (d)	CDI:RfD Ratio
Ammonia (NH3)	2.5E-03	9.71E-01 (e)	--	--	3E-03
Chromium (CR)	6.3E-05 (f)	5.0E-03	500	CNS	1E-02
Fluoride (F)	1.1E-02	6.0E-02	1	Teeth	2E-01
Manganese (MN)	2.0E-03	1.0E-01	1	CNS	2E-02
Mercury (HG)	8.5E-06	3.0E-04	1,000	Kidney	3E-02
Nitrite (NO2)	4.7E-04	1.0E-01	10	Blood	5E-03
Zinc (ZN)	3.5E-03	2.0E-01	10	Blood (Anemia)	2E-02
HAZARD INDEX	--	--	--	--	< 1 (3E-01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron, sulfate, and sulfide.
(b) USATHAMA chemical codes listed in parentheses.
(c) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(d) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(e) The RfD for ammonia, based on a taste threshold, was converted from mg/L to mg/kg-day by assuming that a 70 kg adult drinks 2 liters of water per day.
(f) The RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.

TABLE 7-31

POTENTIAL RISKS ASSOCIATED WITH FUTURE INGESTION
OF GROUNDWATER AT CANAL CREEK
SALVAGE YARD (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Chloroform (CHCL3)	1.1E-05	6.1E-03	B2	6E-08
1,1-Dichloroethene (11DCE)	7.5E-06	6.0E-01	C	5E-06
bis(2-Ethylhexyl)phthalate (B2EHP)	2.7E-03	1.4E-02	B2	4E-05
Methylene Chloride (CH2CL2)	7.5E-05	7.5E-03	B2	6E-07
1,1,2,2-Tetrachloroethane (TCLEA)	7.9E-03	2.0E-01	C	2E-03
1,1,2-Trichloroethane (12TCE)	1.2E-04	5.7E-02	C	7E-06
Trichloroethene (TRCLE)	1.2E-03	1.1E-02	B2	1E-05
Beryllium (BE)	4.9E-06	4.3E+00	B2	2E-05

TOTAL	--	--	--	2E-03

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Chloroform (CHCL3)	3.7E-05	1.0E-02	1,000	Liver	4E-03
1,1-Dichloroethene (11DCE)	2.6E-05	9.0E-03	1,000	Liver	3E-03
trans-1,2-Dichloroethene (T12DCE)	1.5E-03	2.0E-02	1,000	Blood	8E-02
Di-n-octylphthalate (DNOP)	6.9E-04	2.0E-02	1,000	Liver/Kidney	3E-02
bis(2-Ethylhexyl)phthalate (B2EHP)	9.4E-03	2.0E-02	1,000	Liver	5E-01
Methylene Chloride (CH2CL2)	2.6E-04	6.0E-02	100	Liver	4E-03
1,1,2,2-Tetrachloroethane (TCLEA)	2.8E-02	4.6E-04	1,000	Liver/WBC	6E+01
1,1,2-Trichloroethane (12TCE)	4.1E-04	4.0E-03	1,000	Clinical chem.	1E-01
Trichloroethene (TRCLE)	4.2E-03	7.35E-03	1,000	Liver	6E-01
Ammonia (NH3)	3.1E-03	9.71E-01 (f)	--	--	3E-03
Beryllium (BE)	1.7E-05	5.0E-03	100	Various organs (tumors)	3E-03
Boron (B)	1.0E-03	9.0E-02	100	Testes	1E-02
Chromium (CR)	6.4E-04	5.0E-03 (g)	500	CNS	1E-01
Copper (CU)	5.0E-04	3.71E-02 (h)	1	GI Tract	1E-02
Fluoride (F)	3.7E-03	6.0E-02	1	Teeth	6E-02
Manganese (MN)	3.5E-03	1.0E-01	1	CNS	3E-02
Nickel (NI)	5.8E-03	2.0E-02	300	Body weight	3E-01
Nitrite (NO2)	2.9E-03	1.0E-01	10	Blood	3E-02
Nitrite/Nitrate (NIT)	7.8E-03	1.0E-01 (i)	10	Blood	8E-02
Selenium (SE)	4.4E-05	3.0E-03	15	Skin	1E-02
Zinc (ZN)	9.4E-03	2.0E-01	10	Blood (Anemia)	5E-02

HAZARD INDEX	--	--	--	--	> 1 (6E+01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: iron and sulfate.
(b) USATHAMA chemical codes listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects:
  [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and
  [C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.
(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(f) The RfD for ammonia, based on a taste threshold, was converted from mg/L to mg/kg-day by assuming that a 70 kg adult drinks 2 liters of water per day.
(g) The RfD reported is for chromium VI, as all chromium is conservatively assumed to be in the more toxic form of chromium VI.
(h) Drinking water standard reported in mg/L was converted to mg/kg-day by assuming a 70 kg adult drinks 2 liters of water per day.
(i) The RfD for nitrite is used for nitrite/nitrate (NIT).

Dermal and inhalation exposures in workers during use of groundwater for drinking water could contribute additionally to these estimates of risk. However, these exposures are probably negligible relative to ingestion exposures since workers are not likely to dermally contact tap water frequently and are not likely to take showers at work (which could possibly result in appreciable inhalation exposures).

As discussed in Section 7.2.2, no toxicity criteria information was available for several of the chemicals of potential concern in groundwater (i.e., aluminum, ammonia, iron, lead, sulfate, sulfide, 1,4-oxathiane, and 4-bromofluorobenzene). These chemicals were therefore not quantitatively evaluated, although they could contribute to estimates of risk or hazard. The chemical potentially contributing the most significantly to risk or hazard estimates is lead, which was selected as a chemical of potential concern for the surficial and Canal Creek aquifers. Lead is known to be very toxic to humans and has been associated with a variety of effects, including neurological and developmental effects and cancer. The RME exposure concentration for lead of 6.1 µg/L exceeds the proposed drinking water maximum contaminant level of 5 µg/L. It could contribute to estimates of the impact associated with ingestion of groundwater from the Canal Creek aquifer.

7.3.3.2.2 Inhalation of Chemicals That Have Volatilized from Groundwater During Use

If groundwater wells were reopened in the Canal Creek study area, workers could be exposed to chemicals in the groundwater via other pathways, such as inhalation or dermal absorption during industrial operations. The surficial and Canal Creek aquifers and the groundwater at the Salvage Yard were found to be highly contaminated with many organic compounds. Because most of the organic chemicals are volatile, workers could be exposed via inhalation of chemicals that have volatilized during industrial activities. In addition, dermal absorption of chemicals could also occur.

7.4 ECOLOGICAL ASSESSMENT

This section evaluates potential ecological impacts associated with the chemicals of potential concern at Canal Creek study area in the absence of remediation. The methods used to assess ecological impacts follow those outlined in Chapter 4 and roughly parallel those used in the human health risk assessment. Below, potentially exposed populations (receptors) are identified. Then information on exposure and toxicity is combined to derive estimates of potential impact in these populations. It is emphasized that this ecological assessment is a predictive assessment. Comprehensive field studies of ecological impacts have not yet been conducted in the Canal Creek study area.

This ecological assessment is divided into four principal sections. Section 7.3.1 describes the habitat of the area and identifies the potential receptor species or species groups selected for evaluation. Section 7.3.2 evaluates and provides estimates of potential exposures for the chemicals and receptors of potential concern. Section 7.3.3 summarizes relevant toxicity information for the chemicals of potential concern, and Section 7.3.4 provides estimates of ecological impact.

7.4.1 RECEPTOR CHARACTERIZATION

Most of the Canal Creek study area (approximately 75%) is developed. The rest is made up of forests and wetlands. The forested areas are primarily in the northern and western portions of the study area and are comprised of deciduous species. Estuarine, emergent, irregularly flooded wetlands comprise the majority of the wetlands in the area and are located along the West Branch of Canal Creek. Most of the land adjacent to the East Branch is regularly mowed, however a small area of estuarine, emergent, irregularly flooded wetlands occurs near its confluence with the main branch of Canal Creek. Small pockets of seasonally or temporarily flooded palustrine forested and scrub shrub wetlands occur in the northern portions of the study area. Surface water in the study area consists of Canal Creek and its tributary branches, the Gunpowder River, and a few man-made ponded areas. Figure 7-2 depicts the principal habitat characteristics of the Canal Creek study area.

The Canal Creek study area probably supports a variety of wildlife species. Species characteristic of disturbed and developed land are probably the predominant species, given the prevalence of this habitat type in the Canal Creek area. Probable resident mammalian species of the developed areas include the woodchuck (*Marmota monax*), eastern chipmunk (*Tamias striatus*) house mouse (*Mus musculus*), Norway rat (*Rattus norvegicus*), and gray squirrel (*Sciurus carolinenis*). Common bird species in these areas likely include the pigeon (*Columba livia*), mourning dove (*Zenaida macroura*), house sparrow (*Passer domesticus*), robin (Turdus migratorius), mockingbird (*Mimus polyglottos*), cardinal (*Richmondena cardinalis*), blue jay (*Cyanocitta cristata*), and eastern kingbird (*Tyrannus tyrannus*).

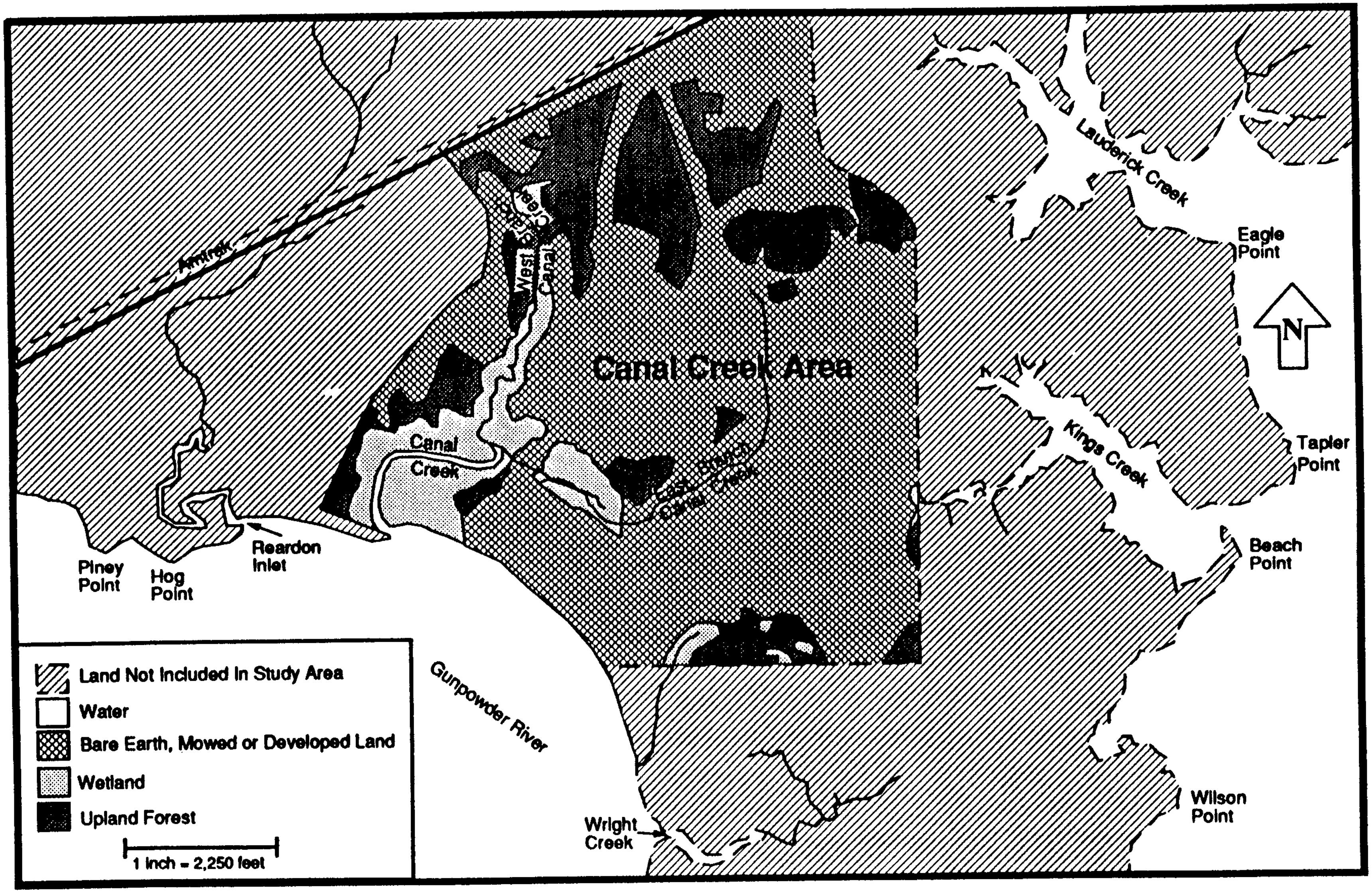
The forested areas of the Canal Creek study area are limited in size and fragmented, somewhat restricting their value as wildlife habitat for larger animals. However, deer are present in the area. The area also supports a diversity of smaller wildlife species. Likely mammalian species in the wooded areas include the gray squirrel, eastern chipmunk, red fox (*Vulpes fulva*), opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), and white-footed mouse (*Peromyscus leucopus*). Raccoon (*Procyon lotor*) probably occur in the forested areas along northern end of the Canal Creek. Probable bird species include woodpeckers (*Dendrocopus sp.*), woodcock (*Philohela minor*), wood thrush (*Hylocichla mustelina*), and a variety of warblers and other song birds. Salamanders are probably common in the wooded areas.

The wetland areas likely support mammalian species such as the muskrat (*Ondatra zibethicus*), shrew (*Sorex cinereus, Blarina brevicauda*), and opossum. Great blue heron (*Ardea herodias*), green heron (*Butorides striatus*) and other wading bird species, mallard (*Anas platyrhynchos*), black duck (*Anas rubripes*) and other dabbling ducks, and a variety of shorebirds, including spotted sandpiper (*Actitis macularia*), yellowlegs (*Tringa* spp.), and rails (*Rallus* spp.) are probably present. Frogs probably are abundant in the wetland areas.

Canal Creek probably provides aquatic habitat for a variety of freshwater and estuarine aquatic life. Most of the fish populations are likely limited to the lower portions of Canal Creek, below the confluence of the East and West Branches. The creek is much shallower upstream of this point and unlikely to support significant fish populations. Freshwater and estuarine fish that have been caught in Canal Creek include largemouth bass (*Micropterus salmoides*), black drum (*Pogonias cromis*), carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavenscens*), striped bass (*Morone saxatilis*), white perch (*Morone americana*), and various species of herrings (*Alosa* spp., *Brevoortia tyrannus*) (AEHA 1985). Invertebrates identified in Canal Creek sediments include polychaetes, oligochaetes, isopods, amphipods, and a variety of freshwater insects (AEHA 1987).

As discussed in Chapter 4, it is not feasible to assess potential impacts in each of the species potentially present in the Canal Creek study area, and for this reason indicator species or species groups are selected for further evaluation. The selection of indicator species for the Canal Creek study area was driven by several factors including the potential for exposure, the sensitivity of

Figure 7-2
Habitat Characteristics of the Canal Creek Study Area At Aberdeen Proving Ground



susceptibility to chemical exposures, the availability of chemical data for potential exposure media, ecological significance, and societal value. The indicator species or species groups selected for evaluation at Canal Creek based on these considerations are a subset of those identified as potential indicators in Chapter 4 and are listed below along with the rationale for their selection.

Aquatic Species

Fish:

- Herrings. This species group was selected for evaluation because juveniles of several members in this family could use Canal Creek as a nursery area (i.e., blueback herring, bay anchovy, menhaden) and thus are vulnerable to population impacts due to juvenile mortality. Several species within this family are commercially important.

Invertebrates:

- Benthic invertebrates. This species group was selected because they are especially vulnerable to exposure to sediment contaminants. Several potentially toxic chemicals have been detected at relatively high levels in the sediments of Canal Creek. Some members of this group are susceptible to exposures to chemicals being released from groundwater to surface water through sediments. They also are an important component of the diet of many birds, as well as adult and juvenile fish.

Terrestrial Species

Birds:

- Great blue heron. This species was selected for evaluation because of its susceptibility to exposure to chemicals in Canal Creek. Several of the chemicals of potential concern in Canal Creek surface water can bioaccumulate in fish, the principal food item in the diet of great blue herons.

- Spotted sandpiper. This species was selected for evaluation because of its probable frequent use of the Canal Creek area and its susceptibility to exposure to chemicals in Canal Creek. This species feeds principally on insects (aquatic larvae and adults). Several of the chemicals of potential concern in Canal Creek can bioaccumulate in aquatic insects, often to a much greater degree than in fish.

Mammals:

- Muskrat. This species was selected for evaluation because its small home range and dependence on aquatic vegetation for food render it susceptible to exposure to chemicals in Canal Creek. Muskrat is a commercially important furbearer at APG.

The other species listed in Chapter 4 as potential indicator species were not selected for evaluation at Canal Creek either because Canal Creek does not provide optimal or preferred habitat; or because they are present in the area but their exposures and/or risks are likely to be less than or equal to that for a selected species. For example, white perch, striped bass, and catfish would be found only occasionally in Canal Creek, as these species prefer the more open waters of the Gunpowder River and the Chesapeake Bay. Green frogs are likely to be present in Canal Creek, but exposures and risks to aquatic larvae are likely to be no greater than those to juvenile herring. Deer are likely to be exposed to a lesser degree than muskrat because they do not eat aquatic vegetation, which could accumulate the chemicals of potential concern. Raccoons are likely to be more common in the forested areas along the northern portions of the West Branch of Canal Creek, which is considered a background location for this study, than in the marshy areas further downstream where surface water samples were collected and contamination is suspected to be greatest. Therefore, exposure of raccoons would be less than muskrats, which live in the marshy portions of the creek. Killifish and bluegill are probable residents of Canal Creek but their exposures are not likely to be greater than those of herring. Mallards (an aquatic herbivore) and bald eagles (which forage over tens of square miles) would have significantly less exposure than the other bird species selected for evaluation.

Appendix D provides species profiles for the vertebrate species selected for evaluation. These profiles should be consulted for information on the ecology of the selected indicator species. Such profiles are not provided for benthic invertebrates due to the large diversity of species comprising this broadly defined receptor group.

7.4.2 POTENTIAL EXPOSURE PATHWAYS AND QUANTIFICATION OF EXPOSURE

In this section, the potential pathways by which the selected indicator species and species groups could be exposed to the chemicals of potential concern at Canal Creek are discussed, and exposure is quantified for selected exposure pathways. This exposure assessment focuses on potential exposures to chemicals in surface water and sediment. No pathways exist by which wildlife could be exposed to chemicals of potential concern in groundwater[6]. Wildlife could be exposed to chemicals in surface soils in the Canal Creek industrial area, between the East and West Branches of Canal Creek. These exposures are not evaluated here, however, as this assessment focuses on potential impacts in wildlife species occupying more natural, less disturbed habitats (i.e., the wetlands along Canal Creek).

Potential exposures are described separately in the following sections for aquatic and terrestrial receptors. For both aquatic and terrestrial wildlife exposures, it was assumed that all mercury in Canal Creek is in the inorganic form. Inorganic mercury present in sediments can be methylated by microorganisms to methylmercury, but a review of the literature on mercury levels in sediments shows that organic mercury normally makes up 0.01-1% of the total mercury concentration in freshwater and marine sediments (Stary et al. 1980, Battelle 1987) and that total mercury concentration is virtually an estimate of inorganic mercury concentrations (Jackson 1986).

7.4.2.1 Aquatic Life Exposures

As discussed in Chapter 4, aquatic life could be exposed to chemicals in surface water and sediment by several pathways. However, most available aquatic toxicity data express toxicity as a function of the concentration in the exposure medium (i.e., surface water or sediment concentration). To be consistent with available toxicity data, exposures to aquatic life are evaluated in this assessment by using surface water and sediment concentrations for Canal Creek.

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[6] Groundwater released to surface water is evaluated as surface water exposure.

Measured concentrations are used to evaluate surface water and sediment exposures. The exposure concentration is the lower value of the upper 95% confidence limit on the arithmetic mean or the maximum detected concentrations. The surface water exposure point concentrations for the East and West Branches of Canal Creek are presented in Tables 7-32 and 7-33, respectively. The inorganic chemical concentrations are total concentrations and are used to evaluate aquatic life exposures instead of dissolved concentrations, as recommended by EPA.[7] The sediment exposure point concentrations for Canal Creek are presented in Table 7-34.

7.4.2.2 Terrestrial Wildlife Exposures

As discussed in Chapter 4, terrestrial wildlife could be exposed to chemicals in surface water and sediment by a variety of pathways. Because adequate data are not available to assess wildlife exposures via all pathways, however, only exposures via ingestion of surface water and food were selected for consideration in the ecological assessments for the various APG study areas. For this assessment of the Canal Creek area, only ingestion of contaminated food was evaluated. Ingestion of surface water was not selected for evaluation because exposures and impacts via this pathway are likely to be insignificant compared to those from the ingestion of food that has accumulated chemicals at concentrations greater than those in the surrounding media. Wildlife exposures were evaluated only for chemicals in the West Branch of Canal Creek. Wildlife exposures to chemicals in the East Branch of Canal Creek were not evaluated because most of the land adjacent to the East Branch of Canal Creek is regularly mowed and provides minimal habitat for the terrestrial species being evaluated.

Chemical concentrations in wildlife food in the Canal Creek study area are estimated in this assessment using bioconcentration factors (BCFs) and chemical concentrations in Canal Creek. BCFs provide a measure of the extent of chemical partitioning at equilibrium between a biological medium such as fish or plants and an external medium such as water. For most chemicals and most situations, water is considered to be the predominant source of chemical residues in aquatic organisms (Neff 1979), and therefore use of an organism:water BCF to estimate chemical concentrations in aquatic life in Canal Creek is a reasonable approach in the absence of measured tissue concentrations. The principal exceptions to this are highly hydrophobic organic compounds such as PCBs, DDT, and dioxins, which tend to accumulate significantly in the aquatic food chain. For these chemicals, use of an organism:water BCF would generally underestimate bioaccumulation because exposures through the food contribute more significantly to total tissue burdens than exposure to chemicals in water. Further, because these chemicals are highly hydrophobic, they typically are not present at appreciable (or even detectable) levels in the water column but tend to partition to sediments in aquatic systems. For these reasons, it is most appropriate to estimate bioaccumulation for these chemicals using organism:sediment BCFs. This approach was used in this assessment for the highly hydrophobic chemicals in Canal Creek sediments.

Information on the bioaccumulation potential of the chemicals of potential concern in Canal Creek was obtained from the available literature. A summary of bioaccumulation data for the chemicals of potential concern is presented in the chemical-specific ecological toxicity profiles presented in Appendix C. In selecting BCFs for use in this risk assessment, the following screening procedures were used.

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[7] Personal communication, EPA Office of Water, Regulations and Standards, 1989.

TABLE 7-32

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER IN THE EAST BRANCH OF CANAL CREEK

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Chlorobenzene (CLC6H5)	1	2.2	1.4	1.4
1,1-Dichloroethene (11DCE)	4.9	12	7	7
trans-1,2-Dichloroethene (T12DCE)	3.7	15	7.5	7.5
Methylene Chloride (CH2CL2)	7.9	96	17.4	17.4
1,1,2,2-Tetrachloroethane (TCLEA)	14	190	24	24
Trichloroethene (TRCLE)	4.9	22	10.3	10.3
Vinyl Chloride (C2H3CL)	1.4	1.5	1.4	1.4
Inorganic Chemicals (d):				
Barium (BA)	53	89	80.3	80.3
Beryllium (BE)	5.2	14,000	11.8	11.8
Boron (B)	170	360	295	295
Cadmium (CD)	1.2	2.4	1.9	1.9
Chromium (CR)	5.8	160,000	13	13
Copper (CU)	5	15	8	8
Fluoride (F)	220	290	255	255
Iron (FE)	1,700	2,800	2,450	2,450
Lead (PB)	5.7	9.3	7.6	7.6
Nickel (NI)	4.7	150	8.6	8.6
Nitrite/Nitrate (NIT) (e)	290	1,500	440	440
Silver (AG)	0.2	1.1	0.5	0.5
Sulfate (SO4)	37,000	42,000	41,500	41,500
Zinc (ZN)	48	67	60	60

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Total concentrations reported.
(e) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

TABLE 7-33

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER IN THE WEST BRANCH OF CANAL CREEK

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Butylbenzylphthlate (BBZP)	14	40	25.7	25.7
Carbon Tetrachloride (CCL4)	4.1	5.4	11.0	5.4
Chlorobenzene (CLC6H5)	2.0	2.3	3.5	2.3
Chloroform (CHCL3)	5.5	12	15.6	12
trans-1,2-Dichloroethene (T12DCE)	2.9	3.5	5.9	3.5
1,3-Dichloropropene (13DCPE)	2.7	3.1	5.5	3.1
Ethylbenzene (ETC6H5)	4.2	5.3	13.8	5.3
Methylene Chloride (CH2CL2)	7.7	11	15.5	11
1,1,2,2-Tetrachloroethane (TCLEA)	5.3	7.6	11.5	7.6
Tetrachloroethene (TCLEE)	2.3	2.6	4.1	2.6
Trichloroethene (TRCLE)	4.0	5.2	7.4	5.2
Trichlorofluoromethane (CCL3F)	2.7	3.0	4.5	3.0
Vinyl Chloride (C2H3CL)	1.3	1.5	2.0	1.5
Inorganic Chemicals (d):				
Aluminum (AL)	580	870	2,400	870
Arsenic (AS)	2.1	2.9	3.8	2.9
Barium (BA)	45	58	106	58
Cadmium (CD)	1.2	1.5	2.7	1.5
Chromium (CR)	4.1	9.7	13.0	9.7
Copper (CU)	8.3	9.3	11	9.3
Cyanide (CN)	5.2	5.6	7.5	5.6
Fluoride (F)	180	270	363	270
Lead (PB)	12	15	23	15
Manganese (MN)	300	460	611	460
Mercury (HG)	0.3	0.3	0.5	0.3
Nickel (NI)	4.3	5.6	9.1	5.6
Nitrite/Nitrate (NIT) (e)	190	540	775	540
Silver (AG)	0.3	0.4	0.6	0.4
Sulfate (SO4)	25,000	32,000	44,000	32,000
Zinc (ZN)	67	87	159	87

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Total concentrations reported.
(e) Concentration is reported as nitrite/nitrate non-specific. The values reported are assumed to represent the total concentration of nitrite/nitrate.

TABLE 7-34

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SEDIMENT SAMPLES AT CANAL CREEK

(Concentrations reported in mg/kg)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
DDT [Total]	0.055	0.84	0.52	0.52
Dieldrin (DLDRN)	0.015	0.068	0.060	0.060
Hexachlorobenzene (CL6BZ)	0.014	1.2	0.035	0.035
PCB [Total]	2.2	55	5.68	5.68
TCPU	49	120	66	66
2,4,6-Trichloroaniline (246TCA)	0.87	4	1.3	1.3
Inorganic Chemicals:				
Arsenic (AS)	49	230	94.9	94.9
Beryllium (BE)	5.1	8.2	6.3	6.3
Cadmium (CD)	2.5	4	3.9	3.9
Chromium (CR)	86	220	200	200
Copper (CU)	97	390	185	185
Lead (PB)	240	420	527	420
Mercury (HG)	2.5	8,800	5.7	5.7
Nickel (NI)	37	64	68.5	64
Thallium (TL)	43	210	65	65
Zinc (ZN)	510	2,100	894	894

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

- Data from laboratory studies were generally used in preference to field data because laboratory studies involve considerably greater control of the parameters affecting bioaccumulation (e.g., chemical concentration, exposure duration).

- Whole-body BCFs were used in preference to muscle or organ-specific BCFs because wildlife typically ingest an entire organism.

- The highest BCF reported in the literature for the particular species of interest was selected for use in this assessment.

Wildlife exposures to chemicals in food are evaluated only for chemicals with organism:water BCFs greater than 300. As discussed in Chapter 4, BCFs greater than 300 generally are considered to result in significant bioaccumulation in aquatic life (EPA 1989b). This cut-off does not apply to organism:sediment BCFs, as the chemicals with such values are known to accumulate significantly in aquatic life.

Once BCFs have been selected, chemical concentrations in food are estimated using the selected BCF and the measured surface water or sediment concentrations in an equilibrium partitioning model:

$$C_f = C * BCF \qquad \text{(Eq. 4)}$$

where:

C_f = chemical concentration in food (mg/kg);

C_w = chemical concentration in the water column (mg/L) or in the sediment (mg/kg); and

BCF = food:water BCF (mg/kg food per mg/L water) or food:sediment BCF (mg/kg food per mg/kg sediment).

For chemical concentrations in water, the total chemical concentration is used in the bioaccumulation estimates. Data on dissolved chemical concentrations are available. These data were not used in this assessment, however, because the calculated upper 95% confidence limit on the arithmetic mean for dissolved concentrations exceeded that for total concentrations because of the higher variability of the reported dissolved concentrations. The RME surface water and sediment concentrations reported in Tables 7-33 and 7-34, respectively, are used to estimate concentrations in Canal Creek aquatic life.

Wildlife exposures via ingestion of contaminated food were estimated using the following equation:

$$Dose = C_f * FI_f/BW \qquad \text{(Eq. 5)}$$

where:

Dose = exposure (mg/kg bw);

C_f = concentration in food (mg chemical/kg food);

FI_f = daily food intake by wildlife of contaminated aquatic life from Canal Creek (kg); and

BW = body weight (kg).

Quantitative estimates of exposure are provided below for the great blue heron, spotted sandpiper, and muskrat.

7.4.2.2.1 Estimates of Exposures in the Great Blue Heron

Great blue heron are likely to feed in the marshes and surface waters of Canal Creek. This species feeds almost exclusively on aquatic life, with fish being the principal component of the diet. A variety of other aquatic species, including amphibians, reptiles, insects, and crustaceans typically make up a small portion of the diet. Exposures of heron to chemicals that have accumulated in fish are evaluated in this assessment. Fish tissue data collected by AEHA (1985) are not used in this evaluation, because they were collected from only two locations along the West Branch and the main portion of Canal Creek (for which exposures are being evaluated), and therefore are not necessarily representative of accumulation in these portions of the creek.

In selecting the fish:water BCFs for use in this risk assessment, the following screening procedures were used in addition to those identified above.

- BCFs for species potentially occurring in Canal Creek (see Section 7.3.1) were used when available. Information on species that are possible residents of Canal Creek was used over information for species that would use Canal Creek intermittently, because resident species would have a greater exposure duration and, therefore, potentially greater tissue concentrations of chemicals of potential concern.
- The highest BCF reported in the literature for Canal Creek species was selected for use in this assessment. If no BCF was available for species potentially occurring in Canal Creek, the highest BCF reported for freshwater species was selected for use.

Fish:water BCFs are presented in Table 7-35 for the chemicals being evaluated for this exposure pathway. No BCFs are presented for aluminum, arsenic, chromium, copper, cyanide, fluoride, lead, manganese, nickel, silver, zinc, or any of the volatile organic chemicals, as these chemicals of potential concern have fish:water BCFs less than 300. No BCFs are presented for barium, sulfate, iron, and nitrate/nitrite due to lack of data on bioaccumulation of these chemicals. However, based on physicochemical properties, none of these chemicals is expected to accumulate appreciably in aquatic life. No BCFs were found in the literature for butylbenzylphthalate and 1,3-dichloropropene, and therefore bioaccumulation was not evaluated for these chemicals. Based on physicochemical properties alone, 1,3-dichloropropene is probably unlikely to bioaccumulate significantly in fish. Butylbenzylphthalate could bioaccumulate significantly in fish. However, it probably is present on suspended sediments in surface water, and therefore would not be available for uptake.

Table 7-35 also presents a fish:sediment BCF for PCBs. No fish:sediment BCFs were located in the available literature for any of the other chemicals of potential concern in sediment. However, based on physicochemical properties (i.e., log K_{ow}s between 3.5 and 6), all of the organic chemicals of potential concern have the potential to bioaccumulate significantly in aquatic life. Excluding these chemicals from the evaluation could significantly underestimate exposures in heron.

TABLE 7-35

FISH BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF HERON EXPOSURES TO CHEMICALS IN CANAL CREEK SURFACE WATER

Chemical (a)	BCF	Basis	Reference
Cadmium	7,440	26-week, whole body bioconcentration in mosquito fish	Giesy et al. (1977) in Eisler (1985)
Mercury	85,700	75-day, whole body bioconcentration in rainbow trout (Salmo gairdneri)	Niimi and Lowe-Jinde (1984) in EPA (1985a)
PCBs	4.3 (b)	Average fish:sediment bioaccumulation factor reported for fathead minnows exposed for 10 days to PCBs in Great Lakes sediments	Willford et al. (1987)

(a) Only chemicals of potential concern with fish:water BCFs greater than 300 are listed here. See text for rationale.
(b) Fish:sediment BCF.

Concentrations of chemicals in fish were estimated by using the selected BCF and the measured surface water or sediment concentration in the equilibrium partitioning model presented in Equation 4 above. Heron exposures via ingestion of fish were estimated using Equation 5 above. For this assessment, heron were assumed to weigh 3.6 kg and ingest 134 g (0.134 kg) of food each day, of which 70% (94 g) was assumed to be fish (see Appendix D for source of values). Heron were further assumed to obtain 10% of their daily fish intake, or 9.4 g, from Canal Creek. This is a reasonable assumption given the wide availability of suitable heron habitat in the areas surrounding Canal Creek and that heron forage over several square miles (see Appendix D).

The resulting estimates of exposure are presented in Table 7-36.

7.4.2.2.2 Estimates of Exposures in Spotted Sandpiper

Spotted sandpiper are likely to feed in the marshes and shoreline of Canal Creek. This species is an aquatic insectivore and feeds predominantly on sediment-dwelling invertebrates. Insects are the principal component of the diet, although benthic worms, small crustaceans, and small mollusks also may be eaten. This assessment evaluated sandpiper exposure via ingestion of aquatic insects that have accumulated chemicals from Canal Creek.

Chemical concentrations in insects were estimated using the BCF approach outlined above. BCFs for freshwater insects were obtained from the available literature, and the highest reported BCF was selected for use in calculating sandpiper exposure. If no BCF was reported for insects, the highest BCF for benthic worms, small crustaceans, or small mollusks was selected for use. Insect:water BCFs for cadmium, lead, manganese, mercury, and zinc are presented in Table 7-37, as is a benthic worm:sediment BCF for PCBs. For reasons similar to those stated above under heron exposures, no BCFs are presented for the other chemicals of potential concern in surface water or sediment. This could result in underestimates of exposure for the chemicals of potential concern in sediment, which all have the potential to bioaccumulate significantly in aquatic life.

Concentrations of chemicals in sandpiper food were estimated by inputting the selected BCF and the measured surface water or sediment concentration to the equilibrium-partitioning model presented in Equation 4 above. The RME concentrations reported in Table 7-33 and 7-34 were used to estimate concentrations in sandpiper food. The estimated concentrations in insects are presented in Table 7-38.

Sandpiper exposures were estimated using Equation 5. For this assessment, sandpipers were assumed to weigh 43 g (0.043 kg) and ingest 7.5 g (0.0075 kg) of food each day, all of which was assumed to be insects (see Appendix D for source of values). Sandpipers were further assumed to obtain 50% of their daily insect intake, or 3.8 g, from Canal Creek. This is a reasonable and probably conservative assumption given the wide availability of suitable sandpiper habitat in the areas surrounding Canal Creek study area and the fact that sandpipers consume flying (adult) insects in addition to aquatic larvae.
The resulting estimates of exposure are presented in Table 7-38.

7.4.2.2.3 Estimates of Exposures in Muskrat

Muskrats are likely to feed in Canal Creek and the surrounding marshes. This species is an aquatic herbivore and feeds predominantly on shoots, roots, tubers, stems, and leaves of aquatic

TABLE 7-36

ESTIMATED EXPOSURES IN HERON INGESTING FISH THAT HAVE ACCUMULATED CHEMICALS FROM THE WEST BRANCH OF CANAL CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg fish per mg/L water) (b)	Estimated Concentration in Fish (mg/kg fish)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0015	7,440	11	0.029
Mercury	0.0003	85,700	26	0.068
PCBs	5.68 (d)	4.3 (e)	24	0.063

(a) Reported previously in Table 7-33, except as noted.
(b) Reported previously in Table 7-35.
(c) Calculated assuming a heron weighs 3.6 kg and ingests 9.4 g (0.0094 kg) of fish from the West Branch of Canal Creek each day.
(d) Sediment concentration in mg/kg reported previously in Table 7-34.
(e) Fish:sediment BCF.

TABLE 7-37

INVERTEBRATE BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF SANDPIPER EXPOSURES TO CHEMICALS IN CANAL CREEK SURFACE WATER

Chemical (a)	BCF	Basis	Reference
Cadmium	4,190	28-day, bioconcentration in the caddisfly (Hydropsyche betteni)	Spehar et al. (1978) in EPA (1985b)
Lead	1,120	28-day, bioconcentration in stoneflies	Spehar et al. (1978) in EPA (1985c)
Manganese	3,900	Chironomid larvae	Salanki et al. (1982) in AQUIRE (1990)
Mercury	24,000	21-day, bioconcentration in clodoceran (Daphnia magna) (b)	Biesinger et al. (1982)
PCBs	4.9 (c)	Average invertebrate:water bioaccumulation factor reported for Oligochaeta exposed for 10 days to PCBs in Great Lake sediments (d)	Willford et al. (1987)
Zinc	1,130	14-day, bioconcentration in mayfly (Ephemerella grandis)	Nehring (1976) in EPA (1987)

(a) Only chemicals of potential concern with invertebrate:water BCFs greater than 300 are listed here. See text for rationale.

(b) Daphnia are small crustaceans. This information is presented here in the absence of information on bioaccumulation in insects.

(c) Invertebrate:sediment BCF.

(d) Oligochaeta are benthic worms. This information is presented here in the absence of information on bioaccumulation in insects.

TABLE 7-38

ESTIMATED EXPOSURES IN SANDPIPERS INGESTING INSECTS THAT HAVE ACCUMULATED CHEMICALS FROM THE WEST BRANCH OF CANAL CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg insect per mg/L water) (b)	Estimated Concentration in Insects (mg/kg insect)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0015	4,190	6.3	0.56
Lead	0.015	1,120	17	1.5
Manganese	0.46	3,900	1,800	160
Mercury	0.0003	24,000	7.2	0.64
PCBs	5.68 (d)	4.9 (e)	28	2.5
Zinc	0.087	1,130	98	8.7

(a) Reported previously in Table 7-33, except as noted.
(b) Reported previously in Table 7-37.
(c) Calculated assuming a sandpiper weighs 43 g (0.043 kg) and ingests 3.8 g (0.0038 kg) of insects from the West Branch of Canal Creek each day.
(d) Sediment concentration in mg/kg reported previously in Table 7-34.
(e) Organism:sediment BCF.

macrophytes. In Maryland marshes, rushes (*Scirpus* spp.) and cattail (*Typha* spp.) are an estimated 80% of the diet of muskrats (see Appendix D). This assessment evaluates muskrat exposure via ingestion of aquatic macrophytes that have accumulated chemicals from Canal Creek.

Chemical concentrations in macrophytes were estimated using the BCF approach outlined above. BCFs for aquatic macrophytes were obtained from the available literature, and the highest reported BCF was selected for use in calculating muskrat exposure. A plant:water BCF for cadmium is presented in Table 7-39. For reasons similar to those stated previously, no BCFs are presented for the other chemicals of potential concern in surface water.

Cadmium concentrations in plants were estimated by inputting the selected plant:water BCF and the surface water concentration into Equation 5. The RME concentration reported in Table 7-33 was used to estimate cadmium concentration in Canal Creek macrophytes. The estimated concentration in plants is presented in Table 7-40.

Muskrat exposures were estimated using Equation 5. For this assessment, muskrat were assumed to weigh 1.35 kg and ingest 110 g (0.11 kg) of food each day, all of which was assumed to be aquatic macrophytes (see Appendix D for source of values). Muskrat were further assumed to obtain all of their daily food intake from Canal Creek. This is a reasonable assumption because muskrats tend to have small home ranges, on the order of 0.5 acres (see Appendix D).

The resulting estimate of exposure is presented in Table 7-40.

7.4.3 TOXICITY ASSESSMENT

The general methodology for the development of toxicity values for the evaluation of ecological impacts has been described in Chapter 4. The toxicity values to be used to evaluate aquatic life and terrestrial wildlife impacts are presented in this section along with a brief description of the basis of each value. Tables 7-41 and 7-42 present acute and chronic toxicity values for the assessment of aquatic life impacts from exposure to chemicals of potential concern in Canal Creek surface water. Table 7-43 presents toxicity values for the assessment of aquatic life impacts from exposure to chemicals in sediment. Finally, Table 7-44 presents toxicity values for the assessment of impacts in terrestrial wildlife species feeding in Canal Creek. Appendix C presents complete ecological toxicity summaries for all chemicals of potential concern for which exposures are being evaluated.

7.4.4 ESTIMATES OF IMPACT

Impacts to aquatic and terrestrial wildlife exposed to chemicals of potential concern in the Canal Creek study area were evaluated by comparing estimated exposures with the appropriate toxicity value for the chemical and receptors of concern. Exposures that exceed the selected toxicity value suggest that impacts may be possible in the evaluation species or similar species. Potential impacts to aquatic life are discussed below in Section 7.3.4.1, and those to terrestrial wildlife are discussed in Section 7.3.4.2.

TABLE 7-39

PLANT BIOCONCENTRATION FACTOR (BCF) FOR EVALUATION OF MUSKRAT EXPOSURES TO CHEMICALS IN CANAL CREEK SURFACE WATER THAT HAVE ACCUMULATED IN AQUATIC MACROPHYTES

Chemical (a)	BCF	Basis	Reference
Cadmium	960	Bioconcentration in aquatic ferns (Salvinia natans)	EPA (1985b)

(a) Only chemicals of potential concern with meausred BCFs greater than 300 are listed here. See text for rationale.

TABLE 7-40

ESTIMATED EXPOSURES IN MUSKRATS INGESTING AQUATIC MACROPHYTES THAT HAVE ACCUMULATED CHEMICALS FROM THE WEST BRANCH OF CANAL CREEK

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg plant per mg/L water) (b)	Estimated Concentration in Plants (mg/kg plant)	Estimated Dose (mg/kg bw) (c)
Cadmium	0.0015	960	1.4	0.11

(a) Reported previously in Table 7-33.
(b) Reported previously in Table 7-39.
(c) Calculated assuming a muskrat weighs 1.35 kg and ingests 110 g (0.110 kg) of plants from the West Branch of Canal Creek each day.

TABLE 7-41

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER IN THE CANAL CREEK STUDY AREA

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Butylbenzylphthalate (BBZP)	51	96-hour LC50 in shiner perch; factor of 10 applied to account for interspecies variation	Ozretich et al. (1983)
Carbon Tetrachloride (CCL4)	2,700	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
Chlorobenzene (CLC6H5)	4,700	96-hour LC50 in rainbow trout	Dalich et al. (1982)
Chloroform	17,900	96-hour LC50 in bluegill	Anderson and Lusty (1980) in AQUIRE (1990)
1,1-Dichloroethene (11DCE)	7,400	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
1,2-Dichloroethene (12DCE)	22,000	48-hour LC50 in Daphnia; factor of 10 applied to account for interspecies variation	LeBlanc (1980)
1,3-Dichloropropene (13DCPE)	90	48-hour EC50 in Daphnia based on immobilization	Johnson and Finley (1980)
Ethylbenzene (ETC6H5)	2,200	24-hour EC50 in Daphnia based on immobilization	Galassi et al. (1988) in AQUIRE (1990)
Methylene Chloride (CH2CL2)	22,000	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
1,1,2,2-Tetrachloroethane (TCLEA)	930	48-hour LC50 in Daphnia; factor of 10 applied to account for interspecies variation	LeBlanc (1980)
Tetrachloroethene (TCLEE)	1,300	96-hour LC50 in bluegill; factor of 10 applied to account for interspecies variation	Buccafusco et al. (1981)
Trichloroethene (TRCLE)	18,000	48-hour LC50 in Daphnia	LeBlanc (1980)
Trichlorofluoromethane (CCL3F)	3,300	96-hour LC50 in fathead minnow estimated based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for deviation
Vinyl Chloride (C2H3CL)	28,000	96-hour LC50 in saltwater fish estimated based on SAR	See Appendix C for derivation

See footnotes on the following page.

TABLE 7-41 (Continued)

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER IN THE CANAL CREEK STUDY AREA

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Inorganic Chemicals:			
Aluminum (AL)	750	AWQC (freshwater)	EPA (1988a)
Arsenic (AS)	360 (d)	AWQC (freshwater)	EPA (1986)
Barium (BA)	50,000	Estimated threshold level for aquatic toxicity	EPA (1986)
Beryllium (BE)	130	LOEC for acute toxicity (freshwater)	EPA (1986)
Boron (B)	12,000	LC50 in salmon	Eisler (1990)
Cadmium (CD)	8.6 (e)	AWQC (freshwater)	EPA (1985b)
Chromium (CR)	16	AWQC (freshwater)	EPA (1986)
Copper (CU)	34 (e)	AWQC (freshwater)	EPA (1985d)
Cyanide (CYN)	22	AWQC (freshwater)	EPA (1986)
Fluoride (F)	2,700	48-hour LC50 in rainbow trout	Neuhold and Sigler (1960)
Iron (FE)	320	96-hour LC50 in aquatic insects	Warnick and Bell (1969) in EPA (1976)
Lead (PB)	197 (e)	AWQC (freshwater)	EPA (1986)
Manganese (MN)	1,450	96-hour LC50 in rainbow trout	Davies (1980)
Mercury (HG)	2.2	LOEC for acute toxicity in freshwater invertebrates	EPA (1985a)
Nickel (NI)	2,500 (e)	AWQC (freshwater)	EPA (1986)
Nitrate/Nitrite (NIT)	5,000	Estimated threshold level for protection of aquatic life	EPA (1986)
Silver (AG)	0.92	Proposed AWQC (freshwater)	EPA (1990)
Sulfate (SO4)	190,000	LC50 in diatoms; factor of 10 applied to account for interspecies variation	Patrick et al. (1968) in NAS (1972)
Zinc (ZN)	210 (e)	AWQC (saltwater)	EPA (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Value is for trivalent arsenic.
(e) Hardness-dependent criterion (hardness of 200 mg/L as CaCO3 used as lower limit).

-- = No information available.

AWQC = Ambient water quality criteria.
LOEC = Lowest-observed-effect concentration.
SAR = Structure activity relationships.

TABLE 7-42

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER IN THE CANAL CREEK STUDY AREA

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Butylbenzylphthalate (BBZP)	20	Estimated chronic value; extrapolated from an LC50 in shiner perch by applying an ACR of 25	Ozretich et al. (1983)
Carbon Tetrachloride (CCL4)	6,710	14-day LC50 in guppies; factor of 10 applied to account for interspecies variation	Koneman (1981) in AQUIRE (1990)
Chlorobenzene (CLC6H5)	210	30-day LOEC in rainbow trout; factor of 10 applied to account for interspecies variation	Dalich et al. (1982) in AQUIRE (1990)
Chloroform (CHCL3)	124	28-day LC50 in ELS test with rainbow trout	Black and Birge (1980) in AQUIRE (1990)
1,1-Dichloroethene (11DCE)	2,900	7-day LC50 in fathead minnows; factor of 10 applied to account for interspecies variation	Dill et al. (1980) in AQUIRE (1990)
1,2-Dichloroethene (12DCE)	8,800	Estimated chronic value; extrapolated from acute LC50 in Daphnia by applying an ACR of 25	LeBlanc (1980)
1,3-Dichloropropene (13DCPE)	4	Estimated chronic value; extrapolated from an EC50 in Daphnia by applying an ACR of 25	Johnson and Finley (1980)
Ethylbenzene (ETC6H5)	2,900	Estimated chronic value; extrapolated from an EC50 in Daphnia by appling an ACR of 25	Galassi et al. (1988) in AQUIRE (1990)
Methylene Chloride (CH2CL2)	29,400	14-day LC50 in guppies; factor of 10 applied to account for interspecies variation	Koneman (1981) in AQUIRE (1990)
1,1,2,2-Tetrachloroethane (TCLEA)	690	28-day LOEC based on reproductive effects in Daphnia; factor of 10 applied to account for interspecies variation	Richter et al. (1983) in AQUIRE (1990)
Tetrachloroethene (TCLEE)	520	Estimated chronic value; extrapolated from acute LC50 in bluegill by applying an ACR of 25	Buccafusco et al. (1981)
Trichloroethene (TRCLE)	720	Estimated chronic value; extrapolated from LC50 in Daphnia by applying an ACR of 25	LeBlanc (1980)
Trichlorofluoromethane	6,400	14-day LC50 estimated for fish based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation
Vinyl Chloride (C2H3CL)	28,000	14-day LC50 estimated for fish based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation

See footnotes on the following page.

TABLE 7-42 (Continued)

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS
FROM EXPOSURE TO CHEMICALS IN SURFACE WATER IN THE CANAL CREEK STUDY AREA

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Inorganic Chemicals:			
Aluminum (AL)	87	AWQC (freshwater)	EPA (1988a)
Arsenic (AS)	190 (d)	AWQC (freshwater)	EPA (1985e)
Barium (BA)	50,000	Estimated threshold value for aquatic toxicity	EPA (1986)
Beryllium (BE)	5.3	LOEC (freshwater)	EPA (1986)
Boron (B)	6,400	MATC in cladocerans	Eisler (1990)
Cadmium (CD)	2.0 (e)	AWQC (freshwater)	EPA (1985b)
Chromium (CR)	11	AWQC (freshwater)	EPA (1986)
Copper (CU)	21 (e)	AWQC (freshwater)	EPA (1985d)
Cyanide (CYN)	5.2	AWQC (freshwater)	EPA (1985f)
Fluoride (F)	1,500	Delayed hatching in rainbow trout eggs exposed for 7-10 days	Ellis et al. (1948)
Iron (FE)	1,000	AWQC (freshwater)	EPA (1986)
Lead (PB)	7.7 (e)	AWQC (freshwater)	EPA (1986)
Manganese (MN)	10	Growth reduction in Pacific oyster larvae exposed for 14-days	Watling (1983) in AQUIRE (1990)
Mercury (HG)	0.26	Chronic value for fathead minnow	EPA (1985a)
Nickel (NI)	280 (e)	AWQC (freshwater)	EPA (1986)
Nitrate/Nitrite (NIT)	5,000	Estimated level for protection of aquatic life	EPA (1986)
Silver (AG)	0.12	AWQC (freshwater)	
Sulfate (SO4)	76,000 (mg/L)	Estimated chronic value; extrapolated from an LC50 in diatoms by applying an ACR of 25	Patrick et al. (1968) in NAS (1972)
Zinc (ZN)	190 (e)	AWQC (saltwater)	EPA (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Value is for trivalent arsenic.
(e) Hardness-dependent criterion (hardness of 200 mg/L as CaCO3 used as lower limit).

-- = No information available.
ACR = Acute to chronic ratio.
AWQC = Ambient water quality criteria.
LOEC = Lowest-observed-effect concentration.
SAR = Structure activity relationships.

TABLE 7-43

TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE
IMPACTS FROM EXPOSURE TO CHEMICALS IN SEDIMENT IN THE CANAL CREEK STUDY AREA

Chemical (a)	Sediment Toxicity Value (mg/kg)	Basis for Value (b)	Reference
Organic Chemicals:			
DDT (total)	0.31 (c)	Concentration at or above which significant biological effects will occur; based on studies in benthic invertebrates	Barrick and Beller (1989)
Dieldrin (DLRDN)	--	--	--
Hexachlorobenzene (CL6BZ)	--	--	--
PCBs (total)	0.1	Estimated protective level for aquatic life	Field and Dexter (1988)
TCPU	--	--	--
2,4,6-Trichloroaniline (246TCA)	--	--	--
Inorganic Chemicals:			
Arsenic (AS)	16	Estimated safe level in sediments	Barrick and Beller (1989)
Beryllium (BE)	--	--	--
Cadmium (CD)	5.1	Concentration at or above which significant biological effects will occur; based on studies in benthic invertebrates	Barrick and Beller (1989)
Chromium (CR)	260	Concentration at or above which significant biological effects will occur; based on studies in oysters	Barrick and Beller (1989)
Copper (CU)	390	Concentration at or above which significant biological effects will occur; based on sediment toxicity studies with oysters	Barrick and Beller (1989)
Lead (PB)	450	Concentration at or above which significant biological effects will occur; based on studies in benthic invertebrates	Barrick and Beller (1989)
Mercury (HG)	0.8	Estimated threshold concentration based on early lifestage tests in rainbow trout	Birge et al. (1977) in Birge et al. (1987)
Nickel (NI)	140	Concentration at or above which significant biological effects will occur; based on studies in benthic invertebrates	Barrick and Beller (1989)
Thallium (TL)	--	--	--
Zinc (ZN)	760	Estimated threshold concentration based on early lifestage tests in rainbow trout	Birge et al. (1977) in Birge et al. (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) See Appendix C for more study details.
(c) Value is for DDE.

-- = No information available.

TABLE 7-44

TOXICITY VALUES FOR ASSESSMENT OF TERRESTRIAL WILDLIFE IMPACTS FROM EXPOSURE TO CHEMICALS AT THE CANAL CREEK STUDY AREA

		Basis for Value (c)					
Receptor Species/ Chemical (a)	Toxicity Value (mg/kg bw) (b)	Test Species	Exposure Duration	Dose (mg/kg bw)	Effect	Source	Uncertainty Factor
Heron and Sandpiper:							
Cadmium (CD)	0.13	Poultry	Not reported	12.5 (d)	Reduced egg fertility and hatchability	Puls (1988)	100 (to account for interspecies differences and to extrapolate a NOAEL from an effect level)
Lead (PB)	1.2	Kestrel	7 Months	12 (e)	Survival, reproduction	Pattee (1984)	10 (to account for interspecies variation)
Manganese (MN)	51	Turkey	21 Days	510 (d)	NOAEL; decreased growth	Vohra and Kratzer (1968) in NAS (1980)	10 (to account for interspecies variation)
Mercury (HG)	0.41	Chicken, turkey, pheasant, duck	Not reported	0.41 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)
PCBs	0.5	Screech owl	8 Weeks	0.5 (e)	Reproductive effects	McLane and Hughes (1980)	None (NOAEL based on data from 3 or more species)
Zinc (ZN)	7.8	Japanese quail	2 Weeks	7.8 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)
Muskrat:							
Cadmium (CD)	0.015	Domestic mammals	Recommended for long-term exposure	0.015 (d)	Recommended safe level	NAS (1980)	None (value derived to protect a variety of domestic mammals)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using methodology outlined in Chapter 4.
(c) See Appendix C for additional information on the referenced studies.
(d) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages using the dietary conversion factors reported in Lehman (1954). See Appendix C for more detail.
(e) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages based on average body weights in tested species and estimated food intake rates. See Appendix C for more detail.

7.4.4.1 Potential Impacts in Aquatic Life

Aquatic life exposures to chemicals in Canal Creek surface water and sediment were evaluated. Potential impacts are discussed separately below.

7.4.4.1.1 Surface Water

Surface water exposures were evaluated for both the East and West Branches of Canal Creek. Tables 7-45 and 7-46 present a comparison of surface water exposure concentrations in the East and West Branches of Canal Creek with the selected acute and chronic toxicity values. As the comparisons indicate, surface water concentrations of several chemicals exceed acute and/or chronic toxicity values for aquatic life. Inorganic chemicals are the primary chemicals that are elevated above toxicity values. For the East Branch surface waters, chronic toxicity values are exceeded for beryllium, chromium, iron, and silver; the acute toxicity value of iron also is exceeded. For the West Branch surface waters, chronic toxicity values are exceeded for aluminum, cyanide, lead, manganese, mercury, nickel, and silver; the acute toxicity value of aluminum also is exceeded. Butylbenzylphthalate is the only organic chemical in Canal Creek surface water that exceeds toxicity values. It is present in West Branch surface water at concentrations above its chronic toxicity value.

A chemical-specific evaluation of potential impacts on aquatic life ignores the potential toxicity associated with the chemical mixture. Chemicals may act additively, synergistically, or antagonistically. However, generally too few data are available to quantify chemical interactions within mixtures. In the absence of precise information on chemical interactions, a simplistic approach to evaluating chemical mixture toxicity is to assume additivity of effects. Such an assumption may be valid, particularly when all the chemicals under consideration induce toxic effects via the same mechanism of action. There is a large body of literature that shows that the mechanism by which many non-ionizable, industrial organic chemicals (such as the volatile organic chemicals of potential concern in Canal Creek surface water) induce acute toxicity in aquatic organisms is via a nonspecific narcotic or anesthetic mode of action. Abernethy et al. (1988) investigated this narcotic mode of action in aquatic organisms and found a correlation between narcotic effects and the volume fraction of the toxicant at the target site (nerve cell membrane). They hypothesized that the narcotic effect occurs when the sum of the individual chemical volume fractions equals or exceeds a critical volume. Furthermore, they suggested that because of this mode of action, the toxicity of the mixture is related to the toxicity of the individual chemicals of equal molar volume as follows:

$$\frac{1}{LC50_{mix}} = \sum_{i=1}^{N} \frac{C_i}{LC50_i} \qquad \text{(Eq. 6)}$$

where:

C_i = the concentration of each component of the mixture containing N components.

This approach was used in this assessment to evaluate the acute toxicity of the volatile organic chemicals of potential concern in Canal Creek by comparing the LC_{50} of the mixture to the sum of the exposure concentrations for all organic chemicals present in surface water. Total concentrations that exceed the estimated LC_{50} of the mixture may indicate acute toxicity of the mixture. Using this approach, the estimated $LC50_{mix}$ and total exposure concentrations (C_{tot}) are as follows:

TABLE 7-45

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN SURFACE WATER IN THE EAST BRANCH OF CANAL CREEK

Chemical (a)	Toxicity Value (ug/L) (b) Acute	Toxicity Value (ug/L) (b) Chronic	Exposure Concentration (c) (ug/L)	Toxicity Value Exceeded?
Organic Chemicals:				
Chlorobenzene (CLC6H5)	4,700	210	1.4	--
1,1-Dichloroethene (11DCE)	7,400	2,900	7	--
trans-1,2-Dichloroethene (T12DCE)	22,000	2,900	7.5	--
Methylene Chloride (CH2CL2)	22,000	29,400	17.4	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	690	24	--
Trichloroethene (TRCLE)	18,000	720	10.3	--
Vinyl Chloride (C2H3CL)	28,000	28,000	1.4	--
Inorganic Chemicals:				
Barium (BA)	50,000	50,000	80.3	--
Beryllium (BE)	130	5.3	11.8	Chronic
Boron (B)	12,000	6,400	295	--
Cadmium (CD)	8.6	2	1.9	--
Chromium (CR)	16	11	13	Chronic
Copper (CU)	34	21	8	--
Fluoride (F)	2,700	1,500	255	--
Iron (FE)	320	1,000	2,450	Acute, Chronic
Lead (PB)	197	7.7	7.6	--
Nickel (NI)	2,500	280	8.6	--
Nitrite/Nitrate (NIT)	5,000	5,000	440	--
Silver (AG)	0.92	0.12	0.5	Chronic
Sulfate (SO4)	190,000	76,000	41,500	--
Zinc (ZN)	210	190	60	--

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Tables 7-41 and 7-42.
(c) Reported previously in Table 7-32.

-- = No toxicity value exceeded.

TABLE 7-46

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN SURFACE WATER IN THE WEST BRANCH OF CANAL CREEK

Chemical (a)	Toxicity Value (ug/L) (b)		Exposure Concentration (c) (ug/L)	Toxicity Value Exceeded?
	Acute	Chronic		
Organic Chemicals:				
Butylbenzylphthlate (BBZP)	51	20	25.7	Chronic
Carbon Tetrachloride (CCL4)	2,700	6,710	5.4	--
Chlorobenzene (CLC6H5)	4,700	210	2.3	--
Chloroform (CHCL3)	17,900	124	12	--
trans-1,2-Dichloroethene (T12DCE)	22,000	8,800	3.5	--
1,3-Dichloropropene (13DCPE)	90	4	3.1	--
Ethylbenzene (ETC6H5)	2,200	2,900	5.3	--
Methylene Chloride (CH2CL2)	22,000	29,400	11	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	520	7.6	--
Tetrachloroethene (TCLEE)	1,300	520	2.6	--
Trichloroethene (TRCLE)	18,000	720	5.2	--
Trichlorofluoromethane (CCL3F)	3,300	6,400	3.0	--
Vinyl Chloride (C2H3CL)	28,000	28,000	1.5	--
Inorganic Chemicals:				
Aluminum (AL)	750	87	870	Acute, Chronic
Arsenic (AS)	360 (d)	190 (d)	2.9	--
Barium (BA)	50,000	50,000	58	--
Cadmium (CD)	8.6	2	1.5	--
Chromium (CR)	16	11	9.7	--
Copper (CU)	34	21	9.3	--
Cyanide (CN)	22	5.2	5.6	Chronic
Fluoride (F)	2,700	1,500	270	--
Lead (PB)	197	7.7	15	Chronic
Manganese (MN)	1,450	10	460	Chronic
Mercury (HG)	2.2	0.26	0.3	Chronic
Nickel (NI)	2,500	280	5.6	--
Nitrite/Nitrate (NIT)	5,000	5,000	540	--
Silver (AG)	0.92	0.12	0.4	Chronic
Sulfate (SO4)	190,000	76,000	32,000	--
Zinc (ZN)	210	190	87	--

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Tables 7-41 and 7-42.
(c) Reported previously in Table 7-33.
(d) Value is for trivalent arsenic.

-- = No toxicity value exceeded.

- East Branch: $LC50_{mix}$ = 35 µg/L
  C_{tot} = 69 µg/L;
- West Branch: $LC50_{mix}$ = 58 µg/L
  C_{tot} = 60 µg/L.

Thus, when additivity of toxic effects is considered, organic chemical concentrations in both the East and West Branch surface water are possibly acutely toxic to aquatic life.

All of the above comparisons suggest that aquatic life in Canal Creek is being impacted by chemical contaminants associated with the Canal Creek study area. Acute and chronic toxicity in aquatic life in the study area surface waters probably have affected the composition and structure of the aquatic communities in Canal Creek. Although it is difficult to predict the exact nature of such impacts, chemical toxicity may have resulted in a decrease in species diversity and species numbers, as species tolerant of contaminated waters have replaced less tolerant species.

It also is possible that chemical contaminants in Canal Creek are impacting nonresident species that use the area seasonally or occasionally. For example, Canal Creek probably serves as a nursery area for blueback herring, bay anchovy, and menhaden. Larvae and juveniles of these species could experience reductions in survival and growth as a result of exposure to chemicals in Canal Creek. Because Canal Creek is likely to provide nursery habitat for, at most, only a small proportion of the total population of herring, anchovy, and menhaden in the Chesapeake Bay, such impacts alone are unlikely to have significant impacts on the entire populations of these species. However, they could result in localized reductions in population size and could contribute to cumulative impacts associated with APG.

These estimates do not include potential impacts associated with exposure to the other chemicals detected in surface water that were screened from the evaluation because of the large number of chemicals present in surface water. Because the chemicals excluded from evaluation were present infrequently and at low concentrations, they probably would not contribute significantly to overall estimates of impact.

The estimates of impact do not include any of the TICs present in surface water or in groundwater that is discharging to surface water. Nor do they include impacts associated with any of the other chemicals listed in Table 7-13 that are potentially present in Canal Creek surface water but that were not analyzed for in surface water (e.g., agent breakdown products). Exposure to these other compounds could add significantly to estimates of aquatic life impact.

7.4.4.1.2 Sediment

Table 7-47 presents a comparison of sediment exposure concentrations in Canal Creek aquatic life toxicity values. As the table shows, the sediment toxicity values for DDT, PCBs, arsenic, mercury, and zinc are exceeded by the exposure concentrations in Canal Creek sediments by factors ranging from slightly greater than 1 (zinc) to 57 (PCBs).

No sediment toxicity data were located in the available literature for dieldrin, hexachlorobenzene, TCPU, or 2,4,6-trichloroanaline, and therefore the degree to which these chemicals could impact benthic species in unknown. However, based on the limited aquatic toxicity data that is available for these chemicals, the potential for impacts exists. TCPU could be of particular concern because it is

TABLE 7-47

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN CANAL CREEK SEDIMENT

(Concentrations reported in mg/kg)

Chemical (a)	Toxicity Value (b)	Exposure Concentration (c)	Toxicity Value Exceeded?
Organic Chemicals:			
DDT [Total]	0.31 (d)	0.52	Yes
PCB [Total]	0.1	5.68	Yes
Inorganic Chemicals:			
Arsenic (AS)	16	94.9	Yes
Cadmium (CD)	5.1	3.9	No
Chromium (CR)	260	200	No
Copper (CU)	390	185	No
Lead (PB)	450	420	No
Mercury (HG)	0.8	5.7	Yes
Nickel (NI)	140	64	No
Zinc (ZN)	760	894	Yes

(a) USATHAMA chemical codes listed in parentheses. Only chemicals with toxicity values are listed. The following chemicals are not presented due to lack of toxicity criteria: dieldrin, hexachlorobenzene, TCPU, 2,4,6-trichloroaniline, beryllium, and thallium.
(b) Reported previously in Table 7-43.
(c) Reported previously in Table 7-34.
(d) Value is for DDE.

present in relatively high concentrations in the sediments of Canal Creek (36,000-66,000 ug/kg) and is potentially highly toxic to aquatic life. Data on the aquatic toxicity of other substituted ureas indicate that toxic effects are possible at extremely low concentrations in surface water. EPA (1988b) reported algae 4-hour EC_{50} values for 25 substituted ureas in the range of 0.2 µg/L, for 3-(3,4,5-trichlorophenyl)-1,1-dimethylurea, to 3 µg/L for 3-(4-acetylaminophenyl)-1,1-dimethylurea. Even though TCPU is likely to persist principally in sediments, it could be present in sediment pore water or in the water immediately above sediments at concentrations within this range. This could result in impacts in addition to those estimated for the other chemicals of concern in sediment.

Aquatic life may be exposed to other compounds in sediment in addition to those measured. For example, white phosphorus can exist in pure form in anaerobic sediments and, based on historical information, could be present in Canal Creek sediments. White phosphorus is very toxic to aquatic life (see Appendix C) and if released from sediments (e.g., during a storm event) could result in additional impacts on aquatic life. Other chemicals potentially present in, but not analyzed for, in sediments could result in impacts on aquatic life (e.g., agent breakdown products, munitions compounds).

The above comparisons and discussions suggest that the benthic community of Canal Creek is being negatively impacted by sediment contaminants. Toxic effects in benthic species could result in result in alterations in community structure and reductions in species number and species diversity. Benthic species diversity studies conducted by AEHA (1985) at three locations in the Canal Creek study area indicated that species diversity was low in these waters, supporting the predictions of impact in this assessment.

7.4.4.2 Potential Impacts in Terrestrial Wildlife

Dietary exposures were evaluated for terrestrial wildlife feeding in Canal Creek. Table 7-48 presents a comparison of selected toxicity values with estimated exposures in heron, sandpipers, and muskrats. The results of the comparisons follow.

- Estimated exposures of heron feeding on fish from Canal Creek do not exceed the toxicity values derived for heron. Estimated exposures are between 5 and 8 times lower than toxicity values.

- Estimated exposures to cadmium, lead, mercury, PCBs and zinc of sandpipers feeding on insects in Canal Creek exceed the toxicity values derived for sandpipers by factors of slightly greater than 1 to 5.

- Estimated exposure to cadmium of muskrat feeding on plants in Canal Creek exceeds the toxicity value by a factor of 7.

These comparisons suggest that wildlife feeding in Canal Creek could be impacted by exposure to heavy metals in their food. Sandpipers and other birds feeding on aquatic insects and probably other invertebrates are potentially at greatest risk of impact, as several of the inorganic chemicals present in Canal Creek can bioaccumulate significantly in aquatic invertebrates. Piscivorous bird species, such as heron, appear to be at lower risk of impact because most of the metals present in Canal Creek accumulate to a lesser degree in fish than in invertebrates. Further, because heron forage over a large area, only a small proportion of their diet is likely to be fish from Canal Creek. Herbivorous

TABLE 7-48

COMPARISON OF TOXICITY VALUES WITH ESTIMATED DOSAGES FOR TERRESTRIAL WILDLIFE EXPOSED TO CHEMICALS THAT HAVE ACCUMULATED IN FOOD AT THE CANAL CREEK STUDY AREA

Receptor Species/ Chemical (a)	Toxicity Value (mg/kg bw)	Estimated Dosage (b) (mg/kg bw)	Toxicity Value Exceeded ?
Heron:			
Cadmium (CD)	0.13	0.029	No
Mercury (HG)	0.41	0.068	No
PCBs	0.5	0.063	No
Sandpiper:			
Cadmium (CD)	0.13	0.56	Yes
Lead (PB)	1.2	1.5	Yes
Mercury (HG)	0.41	0.64	Yes
PCBs	0.5	2.5	Yes
Zinc (ZN)	7.8	8.7	Yes
Muskrat:			
Cadmium (CD)	0.015	0.11	Yes

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Tables 7-36, 7-38, and 7-40.

species such as muskrat appear to be at risk from dietary exposures to cadmium because of cadmium's relatively high toxicity.

Heavy metal exposures in wildlife are associated with a variety of toxic effects. For example, dietary exposures to cadmium, lead, and mercury have been associated with decreased reproductive success in birds. Such effects could directly affect the health of the wildlife populations in and around Canal Creek, potentially resulting in localized reductions in population size. Because Canal Creek likely supports a small percentage of the total wildlife population of APG, effects in individuals feeding in Canal Creek are unlikely to affect the wildlife population of APG as a whole. Nevertheless, the results of this assessment suggest that the presence of heavy metals in Canal Creek has reduced the value of that area as wildlife habitat. Further, impacts on species in the Canal Creek area could contribute to cumulative impacts associated with APG as a whole (see Chapter 13).

7.5 UNCERTAINTIES

As in any risk assessment, there is a large degree of uncertainty associated with the estimates of human health and ecological risks for the Canal Creek study area. Consequently, these estimates should not be regarded as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the predicted risks and to placing the predicted risks in proper perspective. The principal sources of uncertainty associated with the APG risk assessments were discussed in general in Chapter 4. Some of the key sources of uncertainty associated with the estimates of risk for the Canal Creek study area are summarized below.

7.5.1 UNCERTAINTIES RELATED TO SELECTION OF CHEMICALS FOR EVALUATION

Because of sampling limitations there is a great deal of uncertainty regarding the true nature and extent of contamination in the Canal Creek study area. For example, chemical analyses in all media have not completely addressed the full range of contaminants that may be present. This is an especially important source of uncertainty in this risk assessment, given the wide array of wastes and chemicals potentially present in the Canal Creek study area. Without this type of data, it is not possible to fully evaluate potential risks for this study area.

Uncertainty also arises from the exclusion of tentatively identified compounds (TICs), which were not included in the risk assessment because of a lack of information on their identity and concentrations. Exclusion of these chemicals has probably resulted in some under-estimate of exposures and risk. The magnitude to which risks are underestimated depends on the concentrations of the chemicals as well as their toxicity, which has not been well defined for many of the TICs in the Canal Creek area.

7.5.2 UNCERTAINTIES IN ESTIMATES OF EXPOSURE

Much of the uncertainty in this risk assessment is associated with the estimates of exposure concentrations, in particular for surface water and sediment. Only 16 surface water samples and 6 sediment samples were collected from Canal Creek and its associated branches. Further, it is not known if any of these samples were collected from the creek near the points of groundwater discharge. Therefore, it is difficult to predict with any degree of certainty the nature and extent of contamination (and thus exposure) in Canal Creek. Further, no samples were collected from the Gunpowder River downgradient of the mouth of Canal Creek. Given the past waste disposal practices in the Canal Creek study area, it is highly possible that this area has received significant amounts of contamination as a result of runoff and sediment transport. However, exposures and risks to potential ecological and human receptors in this area were not evaluated.

There also is uncertainty regarding temporal variations in exposure concentrations in Canal Creek. Chemical concentrations in Canal Creek could be influenced significantly by short-term physical changes that occur regularly (e.g., diurnal tidal cycles) and irregularly (seasonal variations in precipitation, storm events). These events may result in large-scale variations in chemical conditions at potential exposure points as a result of dilution or flushing. In addition, short-term transport mechanisms such as surface runoff, sediment resuspension, and increased groundwater migration rates may result in greatly increased contaminant loading over short time periods. These intermittent situations could potentially result in greatly increased exposures and risks, but they cannot be evaluated based on current data because of the lack of a time-equivalent data set.

It was assumed in this risk assessment that chemical concentrations in groundwater will remain constant over the 20-year exposure period evaluated for groundwater ingestion. This assumption could overestimate or underestimate risks depending upon the nature of the sources of groundwater contaminants. It is not possible to derive more realistic estimates of temporal changes in groundwater concentrations, because of the lack of detailed and quantitative information on the characteristics of the sources in the Canal Creek study area.

The estimates of bioconcentration in aquatic life also are very uncertain. These estimates were based on a simplistic partitioning model that assumed equilibrium conditions between the aquatic organism and surface water. The approach also assumed that bioaccumulation in species living in Canal Creek was similar to that reported in the literature for other species. The extent to which either of these assumptions is true affects the accuracy of the exposure estimates. The estimates of bioconcentration did not include several of the chemicals present in sediment that potentially could bioaccumulate significantly in aquatic life. TCPU may be of particular concern given its high measured concentrations in sediments. Further, based on the historical disposal of this chemical in Canal Creek, it potentially could be widespread throughout the watershed.

The assumptions used to estimate intake in both human and terrestrial wildlife receptors also contributes a great deal of uncertainty to the estimates of exposure and impact. Generally, conservative assumptions were used when estimating exposures, which could potentially result in overestimates of actual exposures in the Canal Creek study area.

There are uncertainties associated with the assumption that a certain type of exposure would occur at all, which is particularly relevant for hypothetical future exposure scenarios. For example, it was hypothesized that groundwater could be used for potable or industrial purposes in the future, although this would be extremely unlikely, considering that contamination of the groundwater is well known. This hypothetical situation was evaluated to provide a measure of the degradation of the groundwater as a resource, rather than an estimate of a realistic future risk.

7.5.3 UNCERTAINTIES IN THE TOXICITY ASSESSMENT

There is a great deal of uncertainty associated with the estimates of toxicity in terrestrial and aquatic wildlife in this assessment. For example, no aquatic toxicity data were available for several chemicals, so toxicity was estimated using structure-activity relationships. In other cases, aquatic toxicity data were available but only for a few species and typically only for acute exposures. Similarly, few data were available on toxicity in terrestrial wildlife species, so data on domestic species were used to derive the toxicity values used in this assessment. In these instances, toxicity values were estimated by applying uncertainty factors (divisors) to the data.

No data were available on the toxicity of several of the organic chemicals of potential concern in sediment (e.g., TCPU, dieldrin, hexachlorobenzene, 2,4,6-trichloroaniline). Therefore, exposure and impact could be significantly underestimated.

7.6 PRINCIPAL DATA NEEDS

The investigations to date have not provided a complete and exhaustive characterization of the type and degree of contamination in the Canal Creek study area. As a result, additional investigation is needed to assess more definitively existing or potential impacts on this area. The two principal types of additional data needed are (1) data on the nature and extent of contamination and (2) information on aquatic and terrestrial wildlife exposures and/or impacts. Specific data needs within these two categories are summarized below.

Data on the Nature and Extent of Contamination

- Samples from all media should be analyzed for the range of military-unique and other compounds potentially present in the Canal Creek study area. Investigations to date have focused on a limited number of the chemicals potentially present.

- Additional surface water and sediment samples should be collected from Canal Creek and its associated branches so that the extent of contamination along the entire length of these waters can be determined. Also, surface water and sediment samples should be collected from the Gunpowder River near and downstream of the mouth of Canal Creek. Given the nature of past waste disposal in the Canal Creek study area, it is highly possible that the Gunpowder River has received significant amounts of contamination as a result of runoff and sediment transport.

- Surface water and sediment samples should be collected at varying times to characterize temporal changes in chemical concentrations in these media. Surface water sampling immediately following storm events is critical to characterizing potential impacts associated with increased contaminant loading over short time periods as a result of increased runoff and sediment transport. Given the potentially highly contaminated nature of sediment in Canal Creek, sediment transport could result in significant, short-term exposures for aquatic life.

- Additional investigations should be conducted to locate the points of groundwater discharge to Canal Creek. Surface water samples should be collected from this area so that maximum aquatic life exposures can be assessed. Samples should be collected at varying times to characterize any temporal variations in discharge.

- Additional groundwater sampling is needed to better characterize the depth, size, and chemical concentrations in groundwater plumes in the Canal Creek study area.
- Additional effort should be given to defining more precisely the location of all source areas in the Canal Creek study area. Geophysical surveys could be used.
- Soil gas surveys also could be useful in defining potential source areas, as well as in evaluating potential inhalation risks for persons living and working in the area. Once hot spot areas have been defined, flux boxes should be used to provide a measure of emission rates in these areas.
- Additional soil sampling is needed to permit a more complete characterization of contamination in the study area. A more comprehensive set of surface soil samples should be collected from all areas potentially contaminated as a result of past operations or waste disposal in the Canal Creek area. Surface soil samples should be collected from areas used by humans, as well as from more remote areas that are frequented by wildlife. Subsurface soils should be sampled in suspected source areas to help define the nature and magnitude of contamination in these areas.

Data Related to Wildlife Exposures and/or Impacts

- Fish and invertebrates (both benthic and water-column species) should be collected for whole-body residue analyses. Efforts should be made to collect resident fish species and year-round and seasonal (i.e., aquatic insect larvae) populations of invertebrates. Bottom-feeding and predatory species should be included in the fish samples. Ideally, analytes should encompass the range of chemicals that are potentially present in the area and that have the potential to bioaccumulate in aquatic life (e.g., metals, PCBs, organochlorine pesticides, TCPU). Suitable background samples are needed for evaluation of results.
- Aquatic macrophytes should be collected for residue analysis. Again, analytes should include all chemicals potentially present that could bioaccumulate in plants. Suitable background samples are needed for evaluation of results.
- Surveys of benthic macroinvertebrate species should be conducted along the length of Canal Creek and its associated branches and in the Gunpowder River near and downstream of the mouth of Canal Creek. Studies should include benthic species samples from a suitable background location.
- Sediment toxicity studies are needed to assess impacts associated with chemicals adsorbed onto sediments. Suitable laboratory and field controls are needed.
- Aquatic toxicity tests are needed to assess the toxicity of Canal Creek surface water. Tests should include acute toxicity tests and chronic or early life-stage tests with invertebrates, algae, and fish. Ideally, tests should be conducted with species similar to those living permanently or seasonally in Canal Creek and the Gunpowder River. Tests should be conducted with water from Canal Creek in and away from the groundwater discharge zone and with water from the Gunpowder River.

7.7 SUMMARY AND CONCLUSIONS

This baseline risk assessment for the Canal Creek study area addressed potential impacts on human health and the environment in the absence of remedial actions. Sampling data were available for surface soil, groundwater, surface water, and sediment. Chemical analyses were limited primarily to volatile, semivolatile, and inorganic chemical analyses in all media. In addition to these chemicals, soil samples were analyzed for pesticides, PCBs, and dinitrotoluene, sediment samples were analyzed for pesticides and PCBs, and surface water samples were analyzed for 1,4-oxathiane, dithiane, dinitrotoluene, and selected pesticides.

According to the available sampling data, volatile organic chemicals and inorganic chemicals are the primary chemicals of potential concern in groundwater and surface water. Pesticides, PCBs, TCPU, 2,4,6-trichloroaniline, and inorganic chemicals are the chemicals of potential concern in soil and/or sediment. The majority of the chemicals in groundwater were detected in the Canal Creek and surficial aquifers, whereas the lower confined aquifer contained only elevated levels of some inorganic chemicals, which could be related to background concentrations. The majority of chemicals in surface water were found in the West Branch, where much of the wastes were disposed of.

In addition to sampling conducted to determine contamination in each of the media, historical information provided insight as to the subsurface contamination at Canal Creek. The subsurface soils have not been sampled, because of the uncertainty of what lethal or incapacitating chemicals could be present in great quantities in the disposal areas.

7.7.1 HUMAN HEALTH RISK ASSESSMENT

The principal exposure pathways by which humans might potentially be exposed to chemicals of potential concern in the Canal Creek study area under current land-use are:

- Chronic exposure of grounds maintenance workers via incidental ingestion and dermal absorption of chemicals in surface soil;
- Chronic inhalation exposure of persons living and working in the Canal Creek area to chemicals that have volatilized from surface water and from the subsurface environment (from groundwater, soils, or wastes);
- Chronic or subchronic exposures of people who ingest game that has accumulated chemicals from the Canal Creek study area; and
- Acute inhalation and dermal exposures of workers encountering agent-containing munitions, bulk chemical agents, and unexploded ordnance during excavation or similar activities.

Based on the available data, no other pathways are likely to result in significant exposures under current land-use conditions. Direct contact exposure of groundskeepers was the only pathway selected for quantitative evaluation under current land-use conditions. The other pathways were selected for qualitative evaluation.

The only human exposure pathways potentially complete under future land use conditions are:

- Worker ingestion, dermal contact, and inhalation of chemicals in untreated groundwater from the surficial and Canal Creek aquifers, the lower confined aquifer, and the Salvage Yard groundwater; and

- Worker inhalation exposures to volatile organic chemicals present in untreated groundwater used for industrial purposes.

Although future use of groundwater for potable or nonpotable purposes is very unlikely given the known contamination of groundwater in the area, these pathways were selected as a means of evaluating groundwater in this area as a drinking water or industrial water resource. Drinking water exposures were evaluated quantitatively. Inhalation exposures were evaluated qualitatively.

The estimated human health risks associated with these pathways are as follows:

Current Land Use

- For groundskeepers exposed to chemicals in surface soil, the estimated excess lifetime cancer risk is $3x10^{-7}$. This value is below the $1x10^{-6}$ risk level often used as a benchmark by regulatory agencies in determining the need for corrective action at a hazardous waste site. The total Hazard Index for this pathway is less than 1.

- Persons living and working in the Canal Creek study area could be exposed to chemicals that have volatilized from surface water that has received groundwater discharge and from subsurface wastes, soils, or groundwater. It is not possible at this time to quantitatively evaluate this pathway, given the available data. However, based on the number and type of chemicals present in groundwater in the Canal Creek study area, significant inhalation exposures and risks are possible.

- Hunters could be exposed to chemicals of potential concern that have accumulated in game living in the Canal Creek study area. This pathway cannot be quantitatively evaluated based on the available data. However, several of the chemicals detected in the Canal Creek study area (e.g., PCBs, DDT) could potentially accumulate in terrestrial game species and are potentially very toxic to humans. Potentially significant accumulation could result if large portions of the watershed are contaminated with chemicals that could potentially bioaccumulate in game species. Insignificant accumulation could result if only small portions of the watershed are contaminated with these chemicals.

- Groundskeepers or other individuals involved in subsurface excavation could be exposed to acute hazards if unexploded ordnance or chemical agents were encountered. The chemicals potentially present in the subsurface can cause a variety of toxic effects, ranging from lethality (e.g., mustard) to incapacitation (e.g., adamsite). Because of the potentially high concentrations in the disposal areas, and the severe nature of possible toxic effects, it is concluded that direct contact exposures with chemicals could result in significant health risks to exposed individuals. However, due to the strict protocol required by the Safety Office when "breaking ground," such acute exposures are unlikely to occur.

Future Land Use

- For workers ingesting groundwater from the Canal Creek and surficial aquifer in the main industrial portion of the Canal Creek area, the upper-bound excess lifetime cancer risk is $4x10^{-4}$. This value is above the risk level of $1x10^{-6}$ often used by regulatory agencies in determining the need for corrective action at hazardous waste sites. The estimated excess cancer risks are due primarily to 1,1,2,2-tetrachloroethane, carbon tetrachloride, and vinyl chloride. The Hazard Index for ingestion of groundwater from these two aquifers by future workers is greater than 1, because of the liver toxicants 1,1,2,2-tetrachloroethane and carbon tetrachloride.

- For workers ingesting groundwater from the lower confined aquifer, the Hazard Index is less than 1, indicating that no adverse effects are likely to occur from ingestion of this water. (No potential carcinogens were selected as chemicals of potential concern for this aquifer.)

- For workers ingesting groundwater from the Canal Creek aquifer at the Salvage Yard, the upper-bound excess lifetime cancer risk is $2x10^{-3}$. This value is above the risk level of $1x10^{-6}$ often used by regulatory agencies in determining the need for corrective action at hazardous waste sites and is due primarily to 1,1,2,2-tetrachloroethane. The Hazard Index for ingestion of groundwater from the Salvage Yard by future workers is greater than 1, primarily because of the liver toxicant 1,1,2,2-tetrachloroethane. Dermal and inhalation exposures during use of groundwater as drinking water could add to these risks, but probably not significantly given probable use patterns (i.e., bathing and showering are unlikely).

- Inhalation exposures during industrial use of groundwater could result in inhalation risks, since most of the organic chemicals detected in the Canal Creek and surficial aquifer are volatile, and many of these are known or potential carcinogens.

7.7.2 ECOLOGICAL ASSESSMENT SUMMARY

Potential ecological impacts were evaluated for aquatic and terrestrial wildlife in the Canal Creek study area. Aquatic life exposures were evaluated for chemicals in surface water and sediment of Canal Creek. Terrestrial wildlife exposures were evaluated for heron (a piscivore), sandpiper (an aquatic insectivore), and muskrat (an aquatic herbivore) feeding in the West Branch and main portions of Canal Creek and exposed to chemicals that have accumulated in food. The results of the assessment follow.

Aquatic Life Impacts

- Aquatic life in Canal Creek is probably impacted by chemical contaminants in surface water in the Canal Creek study area. Impacts may be more extensive in the West Branch of Canal Creek than in the East Branch, given the greater number of chemicals present at higher concentrations in this water.

- Chemical concentrations in Canal Creek sediment are below those predicted to be harmful to aquatic life, suggesting that impacts on aquatic life from exposure to chemicals in sediment is possible.

Terrestrial Wildlife

- Wildlife feeding in Canal Creek could be impacted by exposure to heavy metals in their food. Sandpipers and other birds feeding on aquatic insects and probably other invertebrates are potentially at greatest risk of impact as several of the inorganic chemicals present in Canal Creek can bioaccumulate significantly in aquatic invertebrates. Piscivorous bird species, such as heron, appear to be at lower risk of impact because most of the metals present in Canal Creek accumulate to a lesser degree in fish than in invertebrates. Further, because heron forage over a large area, only a small proportion of their diet is likely to be fish from Canal Creek. Herbivorous species such as muskrat appear to be at risk from dietary exposures to cadmium because of cadmium's relatively high toxicity.

7.7.3 CONCLUSIONS OF THE RISK ASSESSMENT

Past activities in the Canal Creek study area have resulted in significant contamination of groundwater, surface water, and sediment. Surface soils in the former manufacturing area are also contaminated. Further, significant contamination of subsurface soils is likely, given past waste disposal practices in the area.

It is not possible at this time to fully evaluate potential human health risks associated with the Canal Creek study area under current land-use conditions. Persons working in the former manufacturing area do not appear to be at significantly increased health risk from contacting surface soil in this area. However, other possible long-term exposure pathways such as inhalation exposures of persons living and working in the area and ingestion of fish or game that has accumulated chemicals cannot be evaluated at this time, given the limited data available to support such evaluations. Workers or other individuals involved in subsurface excavation could be exposed to acute hazards if unexploded ordnance or chemical agent were encountered. Additional human health risks could result if groundwater were used in the future for drinking water or for industrial purposes.

It is possible that aquatic life in Canal Creek and terrestrial wildlife feeding in Canal Creek could be adversely affected by existing chemical contaminant levels.

Acute and chronic toxicity in Canal Creek probably has affected the composition and structure of the aquatic communities in Canal Creek. Localized reductions in species diversity and species numbers are possible, as are impacts in nonresident species that use the area as a nursery area. Because the Canal Creek area supports only a small percentage of the aquatic community at APG, impacts there are unlikely to be significant for the aquatic populations of APG or in the northern Chesapeake Bay. However, they could result in localized reductions in population size and contribute to cumulative impacts of APG (see Chapter 13).

Wildlife feeding in Canal Creek appears to be at risk from exposure to heavy metals in the diet. Dietary exposures to heavy metals can induce a variety of toxic effects in wildlife, including decreased reproductive success, decreased growth, and abnormal behavior. Such effects could directly affect the health of the wildlife populations in and around Canal Creek, potentially resulting in localized reductions in population size. Because Canal Creek probably supports only a small percentage of the total wildlife population of APG, effects in individuals feeding in Canal Creek are unlikely to affect the wildlife population of APG as a whole. Nevertheless, the results of this assessment suggest that the presence of heavy metals in Canal Creek has reduced the value of that area as wildlife habitat.

Further, impacts in species in the Canal Creek area could contribute to cumulative impacts associated with APG as a whole (see Chapter 13).

These estimates of risk, however, should not be regarded as absolute. There is a great deal of uncertainty associated with all risk estimates for the Canal Creek study area due both to limitations associated with the available sampling data as well as limitations inherent to the risk assessment process. Additional investigation is needed to assess more definitively existing and potential impacts associated with the Canal Creek study area.

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8.0 CARROLL ISLAND RISK ASSESSMENT

This chapter evaluates potential impacts on human health and the environment associated with the Carroll Island study area in the absence of remedial (corrective) actions. The hydrogeologic field investigation initiated by USGS in October 1986 and summarized in USGS (1990) is the primary source of sampling data considered in this risk assessment. This study was selected for use in this risk assessment because it was the most recent study conducted at Carroll Island. The data for this study were obtained directly from the USATHAMA database (IRDMS).

The USGS investigation and other investigations conducted to date have not completely characterized the nature and extent of contamination at Carroll Island. Therefore, this risk assessment should be considered largely preliminary and is intended as an initial step in the overall risk assessment process for Carroll Island.

This assessment follows the general methodology outlined in Chapter 4 of this report, which should be consulted for the rationale and further details of the methods used in this assessment. This assessment is organized into eight primary sections:

- Section 8.1 Background Information
- Section 8.2 Selection of Chemicals of Potential Concern
- Section 8.3 Human Health Risk Assessment
- Section 8.4 Ecological Assessment
- Section 8.5 Uncertainties
- Section 8.6 Principal Data Needs
- Section 8.7 Summary and Conclusions
- Section 8.8 References

8.1 BACKGROUND INFORMATION[1]

Carroll Island is located just south of Graces Quarters at the lower west side of APG. It is approximately 855 acres in size. The island is located between Saltpeter and Seneca Creeks, which connect on the west side of the island to separate it from the mainland. The Gunpowder River is to the east, and the Chesapeake Bay is to the southwest. The island is relatively flat and consists of freshwater and estuarine wetlands and open land with sections of forest throughout the island. There are some testing structures on Carroll Island including a test tower, test pads, and wind tunnel. There are a few buildings in the service area including a package sewage treatment plant (see Figure 8-1).

It is not likely that Carroll Island was used from the time it was acquired in 1918 until 1944, although there is no conclusive evidence that testing or training operations were not conducted. Land improvements (e.g. building roads, clearing trees and brush) were started in 1944 to prepare Carroll Island for chemical testing operations. The island was used as the primary open-air chemical agent test site for the Edgewood Area from approximately 1949-1972. Chemical agent testing operations included ground-contamination studies, shock tests, decontamination tests, surveillance tests, and chemical munitions tests. Ground-contamination studies were conducted to determine the length of time an unprotected person should be denied access to a contaminated area. Surveillance tests were

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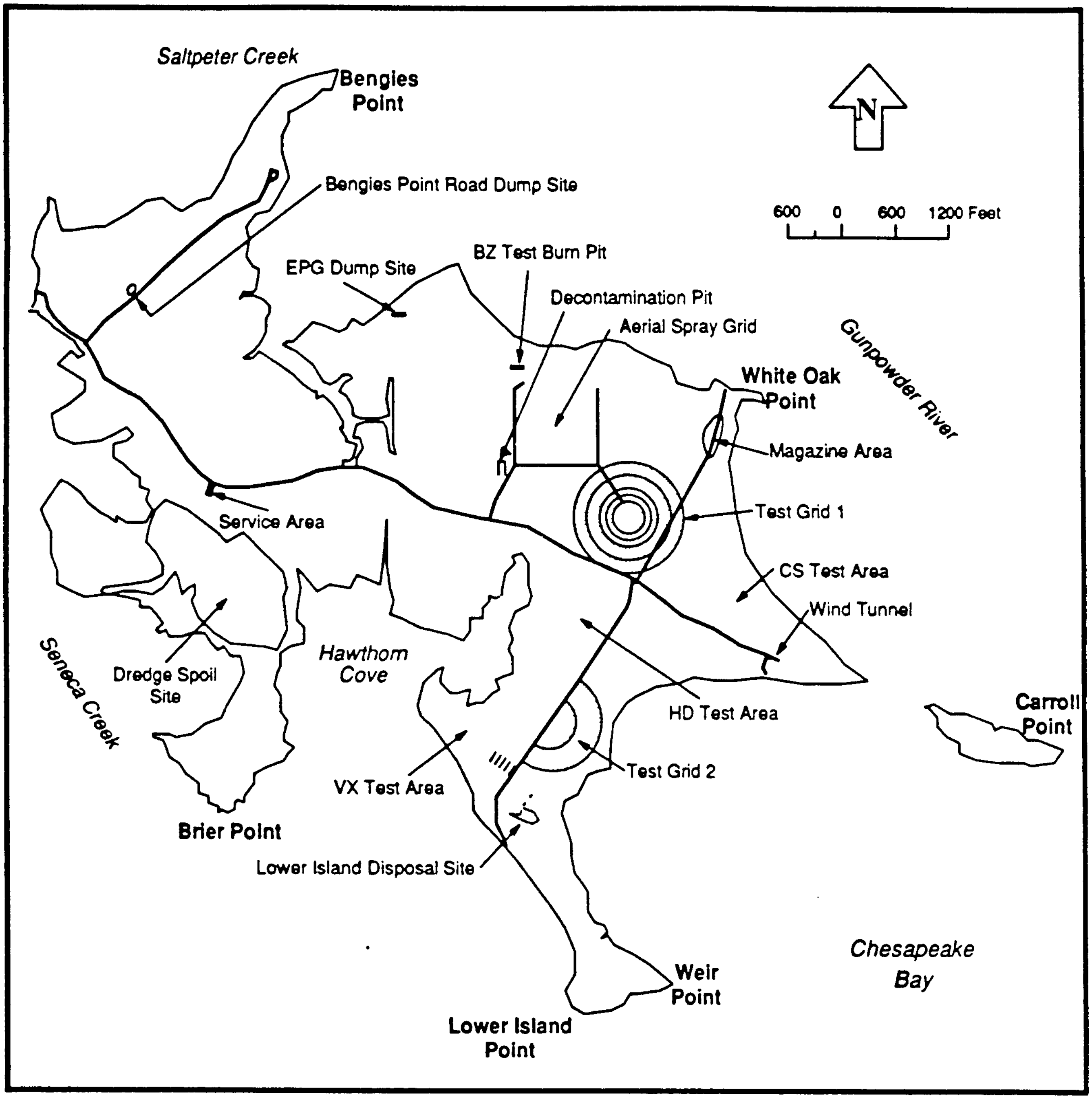
[1] This information is summarized primarily from USGS (1990) and AEHA (1989).

Figure 8-1
Carroll Island Study Area



conducted to determine responses of chemical agent or agent-filled munitions to environmental stresses during storage. Figure 8-1 shows the locations of the possible source areas on Carroll Island.

Information on materials tested or used prior to July 1964 is incomplete although it is known that mustard, chlorobenzene, sarin, VX, white phosphorus, and explosives were tested during this time. Between 1964 and 1971, approximately 13,000 pounds of materials were released at Carroll Island during testing of lethal chemical agents, incapacitating agents, and smoke/incendiary materials. Testing activities at Carroll Island were conducted only when the wind would not blow chemicals towards the western portion of the island.

In addition to chemical agents, other hazardous chemicals such as decontaminating agents, fuel oils, insecticides, and herbicides were used at Carroll Island. Decontamination operations depended on the chemical agent being tested and the type of test. Test areas using tabun and sarin were not decontaminated. Test areas using VX, mustard, or 3-quinuclidinyl benzilate were decontaminated unless persistence tests were being conducted. The total quantity of DANC (5% 1,3-dichloro-5,5-dimethlyhydantoin and 95% 1,1,2,2-tetrachloroethane) used at Carroll Island and Graces Quarters was probably in the tens of gallons. Table 8-1 provides a complete list of compounds believed to have been used or disposed of at Carroll Island.

The primary source areas at Carroll Island are discussed below.

Early Testing Areas. Early testing areas not marked on Figure 8-1 include Carroll Point, the area north of Lower Island Point (part of this area later became Test Grid #2), the water east and southeast of Carroll Island, and an area that later became part of Test Grid #1 and the aerial spray grid. Waste from these testing areas was buried on site. These testing areas were reportedly used to test white phosphorus and high-explosive rounds. Lethal agent rounds were probably not tested in these areas. Flame-thrower tests were probably conducted at the area that later became part of Test Grid #1 and the aerial spray grid. "Surveillance testing of mustard-filled munitions was also performed at unknown locations on Carroll Island during the 1940s and/or the early 1950s" (AEHA 1989).

EPG Dump Site. Waste was dumped in the ditch and along the east edge of the ditch at the EPG dump site sometime between 1943 and the early 1950s. Construction debris and drums of supertropical bleach are visible at the surface of the dump site.

Adamsite Burial Site. The adamsite burial site is reportedly located a short distance into the wooded area west of the spray grid. During the late 1940s or the early 1950s, 10-15 drums of adamsite and chloroacetophenone, which were buried around the time of World War II, were excavated and removed from Carroll Island. The contents of an unknown number of drums that were not intact were spread on the ground surface.

Lower Island Disposal Site. The Lower Island disposal site has between 7 and 11 pits and a marsh dump site located in an area of approximately 4 acres. From the mid- to late 1940s to sometime during the 1950s, wastes were dumped into the marsh along the road. After this, between five and seven pits were dug, filled, and covered with soil north of the treeline north of the marsh. Then another pit farther east by the marsh about 400 feet east of the road was dug, filled, and covered with soil. During the early part of the chemical testing, a bomb crater approximately 12-15 feet in diameter and 6-8 feet deep located on the opposite side of the marsh road was also used as a disposal pit and covered with soil. The exact location of the bomb crater is not known. The last one or two pits are located north of the earlier pits and west of a group of trees. One pit is open at this

TABLE 8-1

PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT CARROLL ISLAND (a)

Group	Chemical Compound (Acronym) (b)
Lethal Chemical Agents	VX Soman (GD) Sarin (GB) Tabun (GA) Distilled Mustard (HD) EA 1356 EA 3990
Incapacitating Agents	o-Chlorobenzylidene Malononitrile (CS) Chloroacetophenone (CN) Adamsite (DM) 3-Quinuclidinyl Benzilate (BZ) Bromobenzyl Cyanide (BBC) EA 3834 EA 3528
Simulants	Talcom powder Furfural Isopropyl Alcohol 1,2,3-Trichloropropane Methylacetoacetate Dibutyl Hydrogen Phosphite (DBHP) Dimethyl Hydrogen Phosphite (DMHP) DEHP [possibly diethyl hydrogen phosphite] Ethylenediamine (EDA) tri(2-Ethylhexyl)phosphate (TOF) bis(2-Ethylhexyl)hydrogen Phosphate
Decontaminating Agents	Decontaminating agent-noncorrosive (DANC) Calcium Hypochlorite (HTH) Sodium Hydroxide (NaOH) Supertropical Bleach (STB) DS-2
Smoke/Incendiary Materials	White Phosphorus (WP) Sulfur Trioxide and Chlorosulfonic Acid Mixture (FS) Triethylaluminum (TEA)
Explosives	High explosives (HE)
Pesticides	Malathion Telvar Dibrom 14
Solvents	1,1,2,2-Tetrachloroethane [major component of DANC] Chloroform Chlorobenzene Carbon Tetrachloride
Miscellaneous Compounds	Fuel oil

(a) Information obtained primarily from USGS (1990) and AEHA (1989).
(b) See Glossary of Acronyms and Abbreviations for complete chemical name if not given in this table.

last area. Two underground bunkers located west of the open pit fill with water during the winter. Contents of the above disposal pits include munitions fragments, sampling equipment, protective clothing, and other solid wastes generated during testing. Items containing lethal agents and explosive items were not supposed to be disposed of in the pits. Items contaminated with lethal agents were supposed to be decontaminated prior to disposal into the pits. Items contaminated with o-chlorobenzylidene malonitrile (CS) or 3-quinuclidinyl benzilate (BZ) were not decontaminated prior to disposal in the pits. There are pieces of munitions in Gunpowder River adjacent to the marsh area that are probably present because of erosion of the dumping area. Steel sheets, pipes, plastic tubing, mask filter, supertropical bleach containers, and DANC containers were found at the surface in the weeded area south of the burial pits. An area north of the tree line where the first pits were dug was used for chemical testing in the late 1960s. CS was the primary chemical agent tested.

Bengies Point Road Dump Site. At the Bengies Point Road dump site solid waste was dumped into a marshy area less than 1 acre in size from the early 1950s to the early 1970s. The water table is shallow, and this area is seasonally submerged. Wastes such as paper, wood, and empty reagent containers, generated during testing activities and not contaminated with chemical agents, were disposed of in this dump. It was abandoned without closure and some items (e.g., personal protective equipment, concrete, other building materials, fragments that might have been CS grenades) are visible on the surface during the dry season.

Decontamination Pits. Two decontamination pits were dug, used, and refilled with the original soil during 1975. Combustible and noncombustible items such as buildings, parts of the test grids, small wind tunnels, and meteorological equipment were burned and reburned in the decontamination pits. Items placed in the pits were not contaminated with detectable levels of toxic chemical agents (AEHA 1989). Some items may have been contaminated with CS. Wood and fuel oil were used to conduct the burns.

BZ Test Burn Pit. The 10-foot-square, 5-foot-deep BZ test burn pit was used briefly in the 1960s to study the effectiveness of disposal of BZ-containing munitions by open pit burning. Metal items were buried in two small pits southeast of the BZ test burn pit. No other information is available about what was buried in the two small pits, the depth of the pits, or the thickness of the soil cover. A mound next to the pit is probably excavated material.

Dredge Spoils Site. Dredge spoils from the channel between Carroll Island and the mainland were deposited in the dredge spoil area during the 1950s or 1960 and again in 1972. The channel was created as part of the Baltimore Gas and Electric Company power plant construction. The dredge spoils site is bermed and probably was a marsh area prior to the deposition of the dredge spoils. Approximately 88,030 cubic yards of dredge spoil were deposited in 1972. An area south of the service area on the northern portion of the dredge spoils was used for ground contamination studies with VX, sarin, and CS.

Test Grid #1. Test Grid #1 was used from the late 1940s until the early 1970s. The actual grid was built in the early 1950s and then rebuilt in 1963. The sampling grid is 400 yards in diameter. The chemical agents were released by spraying, static detonation at or above the ground surface, or firing a projectile or rocket from a tower to the ground surface. Chemical agents were released at or near the center of the grid. All water collected from the inner 20-yard radius circle was pumped to an underground discharge point west-southwest of the test grid. In 1947 or 1948, mustard was tested in the eastern portion of Test Grid #1. Between 1964 and 1971, 1,085.2 pounds of chemicals were released at Test Grid #1. In 1965, 158 pounds of chloroform and dye were released. Solid wastes were disposed of at the Lower Island disposal site. Currently, a 60-foot tower remains near the center of the test grid. Grass, including marsh grass in the wetter areas, has overgrown the grid. Part of the grid is covered with gravelly fill material.

Aerial Spray Grid. The aerial spray grid was used from the late 1940s to the early 1970s. The testing area included a mowed, cleared area as well as adjoining woods and marshes. The primary method of chemical release was by aerial spraying although other chemical tests were conducted. A 60-by-120-foot sampling grid for CS was located in the southwestern portion of the spray grid. Between 1964 and 1971, 4,081 pounds of chemicals were released at the aerial spray grid. In 1965, 50 pounds of chloroform and dye were released. Solid wastes were disposed of at the Lower Island disposal site.

Wind Tunnel. The wind tunnel was used for chemical testing from the early 1960s to 1971. With the exception of a period of time near the end of the testing period when a scrubber was installed and CS was tested, chemical agents were released to the atmosphere. A 250-gallon underground cooling fluid tank (ethylene glycol and water) located south of the wind tunnel was installed in the early to mid 1960s. Between 1964 and 1971, 1,400.3 pounds of chemicals were released at the wind tunnel. Most of the BZ and nearly all of the chloroacetophenone, adamsite, and CS were released at the wind tunnel. The wind tunnel was decontaminated after testing. Decontaminating agents include chlorinating agents (e.g., supertropical bleach), inorganic decontaminants (e.g., sodium bicarbonate), and alcohol-containing solutions. DS-2 and DANC were not used. Wastewater was discharged to a ditch and the marsh area east of the wind tunnel. Solid wastes were disposed of at the Lower Island disposal site. The 20-by-90-foot wind tunnel building and the scrubber still remain.

CS Test Area. This area was used to test the persistence of CS

Test Grid #2. Test Grid #2 was used during the mid-1940s as an impact area for 4.2-inch mortars filled with white phosphorus and high-explosives, and as a chemical agent test area from the late 1940s to 1971. Between 1964 and 1971, 6,244.7 pounds of chemicals were released in and around Test Grid #2. The field is overgrown with grass and about 3-4 inches of gravelly fill material are present in at least part of the test grid.

VX Test Area. Testing of static above-ground functioning of VX-containing rocket warheads in the early 1960s southwest and southeast of Test Grid #2 in the VX test area caused a release of approximately 600 pounds of VX. In the late 1960s, contamination/decontamination studies were conducted on concrete and asphalt pads located southwest of Test Grid #2 and across the north-south road to Lower Island Point.

Mustard Test Area. This area was used for ground-contamination studies of mustard and VX. The extent of the test area is probably just the area that was cleared. The area was decontaminated with supertropical bleach or calcium hypochlorite after mustard was tested. Prior to 1964, approximately 1,500-2,500 pounds of mustard were released over a period of several months by detonating land mines in the mustard test area. East of the HD test area (not located on the source area map), testing operations included tests with small wind tunnels, shock testing of chemical-filled items, and agent penetration of a small portable bunker.

Crossroads Area. Testing operations at the crossroads area (not located on the map) of the north-south road in the eastern half of Carroll Island include surveillance testing of items in environmental chambers and effectiveness testing of items against armored vehicles.

Magazine Area. The magazine area was used for temporary storage of chemical agents and filling of munitions with chemical agents during most of the testing period at Carroll Island. A chain-link fence surrounds the magazine area.

Service Area. The Carroll Island service area consisted of two Quonset huts on concrete pads, a well pumphouse, a water storage tank, and a wastewater package treatment plant. Fuel oil tanks were located above ground. Activities at the service area included minor laboratory work and equipment maintenance. A well was located west of the Quonset huts. During the period when Carroll Island was actively used for chemical agent testing, well water used for nonpotable uses and potable water was brought in from the Edgewood Area because of the naturally unpleasant taste of the groundwater at Carroll Island. Treated wastewater was discharged to the marsh area southeast of the service area. Solid wastes were disposed of in the Bengies Point Road dump site or the Lower Island disposal site. Glass containers, empty supertropical bleach cans, empty cans identified as having contained chemical agent land mines, and gas mask filter canisters were found in the area southeast of the service area near the marsh. A septic tank and drain field system may have been used prior to the construction of the treatment plant. The septic tank and drain field were probably located south of the Quonset huts.

Animal Shelter. An animal shelter (not marked on the source map) was constructed in 1963 or 1964 in the southwest corner of the crossroads located on the eastern half of the island. One of the three existing wells near the crossroads was upgraded for use. There is a cistern adjacent to the southwest side of the animal shelter, and a septic tank and a drain field northwest of the animal shelter. Fuel oil storage tanks are located above ground.

8.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

USGS began a hydrogeologic assessment of Carroll Island in October 1986. Currently, only groundwater and surface water data collected as part of this study are available; soil/sediment samples were collected by USGS from May to October 1990, but are not yet available. Groundwater and surface water samples were collected by USGS in 1988 and 1989. Because it was reported that the laboratory that analyzed the 1988 samples may have falsified sampling results, no data from the 1988 sampling round were included in this assessment.

In this section, the groundwater and surface water monitoring data are presented, and chemicals of potential concern selected for evaluation are identified. The discussions are organized below by environmental medium.

8.2.1 GROUNDWATER

A total of 62 monitoring wells have been installed at Carroll Island around the disposal and testing areas. Forty-nine of these wells were installed by USGS, and 13 wells were installed by USATHAMA in 1977 for an environmental survey of Carroll Island (USATHAMA 1983). Fifty-six wells were installed in the surficial aquifer, and six wells were installed in the confined aquifer. Screen depths ranged from 2.5 to 30 feet for the surficial aquifer wells and from 43 to 65.6 feet for the confined aquifer wells.

For the purposes of this assessment, monitoring wells at Carroll Island were grouped to correspond to the following four areas: (1) the EPG dump site (three surficial aquifer wells); (2) the Bengies Point Road dump site (five surficial aquifer wells and one confined aquifer well); (3) the service area/dredge spoils site (five surficial aquifer wells and one confined aquifer well); and (4) eastern Carroll Island (forty-three surficial aquifer wells and four confined aquifer wells). Wells at the service area were grouped with wells on the dredge spoils site, because these two sites are adjacent to each other. The wells on the eastern half of Carroll Island were grouped into one area because chemical agent testing could potentially have occurred anywhere on the eastern half of Carroll Island. Within each of these groupings, data from the surficial and confined aquifer wells were evaluated separately because they are separate water-bearing units.

Groundwater samples were collected during April and May 1989 (the wet season) and were analyzed for volatile organic chemicals, semivolatile organic chemicals, metals, and other inorganic chemicals. The semivolatile analyses included pesticides, dinitrotoluenes, nitrobenzene, PCBs, 1,4-oxathiane, thiodiglycol, p-chlorophenylmethylsulfone, p-chlorophenylmethylsulfide, and p-chlorophenylmethylsulfoxide. No blank data were available from this study; therefore, it is not possible to determine whether chemicals such as methylene chloride were introduced in the lab or whether they are indicative of site contamination. Groundwater samples for inorganic chemical analyses were filtered in the field. Well I11, located in eastern Carroll Island, was not sampled in 1989.

The results of this sampling are discussed below. As can be seen from the data, very few organic chemicals were detected in the surficial aquifer in any area, and none were detected in the confined aquifer. Although several inorganic chemicals were identified as being potentially elevated above background levels, and therefore were selected as chemicals of potential concern, no site-specific or regional background data were available for groundwater in this area with which to compare site levels. The use of national groundwater data, as was done in this case, introduces considerable uncertainty into this determination. The results of this sampling and the selection of chemicals of concern by area are discussed below.

8.2.1.1 EPG Dump Site

Chemicals detected in surficial aquifer groundwater at the EPG dump site are shown in Table 8-2. No organic chemicals were detected in this groundwater. Aluminum, iron, manganese, silver, thallium, and zinc were present in the surficial aquifer at concentrations above background levels and therefore were selected as chemicals of potential concern. No wells were installed in the confined aquifer at the EPG dump site.

8.2.1.2 Bengies Point Road Dump Site

Chemicals detected in surficial and confined aquifer groundwater at the Bengies Point Road dump site are shown in Table 8-3. The only organic chemical positively identified in the surficial aquifer was methylene chloride, which was detected in one of five samples at a concentration of 47.2 µg/L. Methylene chloride is a common lab contaminant, but because no blank data are available with which to evaluate the site-relatedness of this chemical, it was assumed to be site related for the purposes of this assessment. No organic chemicals were detected in the confined aquifer. Aluminum, barium, iron, manganese, silver, and thallium in the surficial aquifer and manganese in the confined aquifer were present at concentrations above background levels and were therefore selected as chemicals of potential concern. Cyclohexene oxide (1,2-epoxycyclohexene oxide), a tentatively identified compound, was detected twice in the surficial aquifer at a maximum concentration of 4 µg/L as shown in Table 8-4.

TABLE 8-2

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CARROLL ISLAND EPG DUMP SITE

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
Surficial Aquifer (e)			
Inorganic Chemicals:			
* Aluminum (AL)	2 / 3	14,300 - 23,200	100
Barium (BA)	3 / 3	41.9 - 67.9	100
Bromide (BR)	3 / 3	7,350 - 9,710	100
Calcium (CA)	3 / 3	52,000 - 84,000	1,000,000
Chloride (CL)	3 / 3	2,300,000 - 3,100,000	1,000,000
Copper (CU)	3 / 3	11.4 - 15.8	100
Fluoride (F)	3 / 3	2,170 - 3,040	10,000
* Iron (FE)	3 / 3	17,800 - 39,400	10,000
Lead (PB)	2 / 3	3.3 - 7.7	100
Magnesium (MG)	3 / 3	110,000 - 180,000	1,000,000
* Manganese (MN)	3 / 3	506 - 999	100
Nickel (NI)	2 / 3	65.7	100
Nitrite/Nitrate (NIT) (f)	3 / 3	11.6 - 13.7	10,000
Potassium (K)	3 / 3	7,280 - 28,000	10,000
* Silver (AG)	2 / 3	7.8 - 10.1	1.0
Sodium (NA)	3 / 3	850,000 - 1,300,000	1,000,000
Sulfate (SO4)	3 / 3	169,000 - 400,000	1,000,000
* Thallium (TL)	2 / 3	160 - 251	1.0
* Zinc (ZN)	2 / 3	169 - 179	100

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Values reported for metals are dissolved concentrations.
(d) Background concentrations from Walton (1985). Values reported are dissolved concentrations.
(e) Samples: I41, I42, and I43. No samples were collected from the confined aquifer at the EPG dump site.
(f) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.

TABLE 8-3

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CARROLL ISLAND BENGIES POINT ROAD DUMP SITE

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
Surficial Aquifer (e)			
Organic Chemicals:			
* Methylene Chloride (CH2CL2)	1 / 5	47.2	NA
Inorganic Chemicals:			
* Aluminum (AL)	4 / 5	221 - 5,060	100
Arsenic (AS)	2 / 5	4.4 - 5.7	100
* Barium (BA)	5 / 5	22.6 - 274	100
Bromide (BR)	2 / 5	2,750 - 3,080	100
Calcium (CA)	5 / 5	12,100 - 27,500	1,000,000
Chloride (CL)	5 / 5	470,000 - 1,350,000	1,000,000
Copper (CU)	2 / 5	10.7 - 13.7	100
Fluoride (F)	2 / 5	1,190 - 1,520	10,000
* Iron (FE)	5 / 5	81.7 - 83,000	10,000
Lead (PB)	2 / 5	3.3 - 31.5	100
Magnesium (MG)	5 / 5	12,100 - 86,000	1,000,000
* Manganese (MN)	5 / 5	407 - 1,900	100
Nickel (NI)	1 / 5	32.1	100
Nitrite/Nitrate (NIT) (f)	4 / 5	16.1 - 122	10,000
Potassium (K)	5 / 5	1,700 - 13,700	10,000
* Silver (AG)	3 / 5	7.6 - 25.3	1.0
Sodium (NA)	5 / 5	88,000 - 500,000	1,000,000
Sulfate (SO4)	4 / 5	21,200 - 390,000	1,000,000
* Thallium (TL)	3 / 5	113 - 259	1.0
Zinc (ZN)	3 / 5	26.9 - 97.8	100
Confined Aquifer (g)			
Inorganic Chemicals:			
Arsenic (AS)	1 / 1	3.9	100
Barium (BA)	1 / 1	33	100
Calcium (CA)	1 / 1	45,000	1,000,000
Chloride (CL)	1 / 1	120,000	1,000,000
Copper (CU)	1 / 1	11.4	100
Iron (FE)	1 / 1	5,480	10,000
Magnesium (MG)	1 / 1	3,570	1,000,000
* Manganese (MN)	1 / 1	686	100
Potassium (K)	1 / 1	7,760	10,000
Sodium (NA)	1 / 1	41,000	1,000,000

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was deterted divided by the total number of samples analyzed for that chemical.
(c) Values reported for metals are dissolved concentrations.
(d) Background concentrations from Walton (1985). Values reported are dissolved concentrations.
(e) Samples: I50A, I51, I52, I53, and I54A.
(f) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.
(g) Sample: I54B.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-4

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN CARROLL ISLAND GROUNDWATER

(Concentrations reported in ug/L)

Chemical (a)/Site	Number of Detects (b)	Range of Reported Concentrations
Bengies Point Road Dump Site		
Surficial Aquifer:		
Cyclohexene Oxide/1,2-Epoxy-cyclohexene Oxide (12EPCH)	2	3 - 4
Eastern Carroll Island		
Surficial Aquifer:		
Cyclohexene Oxide/1,2-Epoxy-cyclohexene Oxide (12EPCH)	5	3 - 5
4-Methyl-2-pentanone (DIACAL)	3	4 - 7

(a) USATHAMA chemical codes listed in parentheses.
(b) Number of samples in which the chemical was tentatively identified.

8.2.1.3 Service Area/Dredge Spoils Site

Chemicals detected in surficial and confined aquifer groundwater at the service area/dredge spoils site are shown in Table 8-5. Methylene chloride was the only organic chemical detected in the surficial aquifer in this area. This chemical was detected in two of five samples at the dredge spoils site at concentrations of 9.3 µg/L and 47.2 µg/L, respectively. In the absence of blank data, this chemical was assumed to be site-related, although as noted previously it is a common laboratory contaminant. No organic chemicals were detected in the surficial aquifer groundwater at the service area or in the confined aquifer at the service area/dredge spoils site. With respect to inorganic chemicals in this area, aluminum, barium, iron, manganese, silver, and thallium in the surficial aquifer and manganese in the confined aquifer were present at concentrations above background levels and were therefore selected as chemicals of potential concern.

8.2.1.4 Eastern Carroll Island

Chemicals detected in surficial and confined aquifer groundwater at eastern Carroll Island are shown in Table 8-6. The only organic chemicals detected in either the surficial or confined aquifers in this area were acetone, 1,2-dichloroethane, noncarcinogenic PAHs, and trichlorofluoromethane. These chemicals were each detected once in the surficial aquifer and were selected as chemicals of potential concern. Acetone was detected at a concentration of 30.9 µg/L at the Lower Island disposal site, 1,2-dichloroethane was detected at a concentration of 1.4 µg/L at the wind tunnel, noncarcinogenic PAHs were detected at a concentration of 16.8 µg/L at the crossroads south of Test Grid #1, and trichlorofluoromethane was detected at a concentration of 2.1 µg/L at Test Grid #2. Acetone is a common laboratory contaminant and may not be present as a result of past activities at the Lower Island disposal site. Aluminum, barium, iron, manganese, silver, thallium, and zinc in the surficial aquifer and manganese in the confined aquifer were present at concentrations above background levels and were therefore selected as chemicals of potential concern. Two tentatively identified compounds, cyclohexene oxide (1,2-epoxycyclohexene oxide) and 4-methyl-2-pentanone, were detected five times and three times, respectively, in the surficial aquifer at eastern Carroll Island at maximum concentrations of 5 µg/L and 7 µg/L, respectively, as shown in Table 8-4.

8.2.2 SURFACE WATER

Surface water samples were collected from 21 locations in 1989 at Carroll Island around the disposal and testing areas. Surface water sampling locations at Carroll Island were grouped into the following seven areas: the EPG dump site, the Bengies Point Road dump site, the service area, eastern Carroll Island, Chesapeake Bay near the Lower Island disposal site, Chesapeake Bay near the wind tunnel, and Saltpeter Creek. Eastern Carroll Island, the EPG dump site, the Bengies Point Road dump site, and the service area are discrete areas, so they were grouped separately. Chesapeake Bay and Saltpeter Creek sampling locations were grouped separately from inland sampling locations.

Surface water samples were collected in May 1989 (the wet season). They were analyzed for metals and other inorganic chemicals, and volatile and semivolatile organic chemicals. The semivolatile analyses included pesticides, dinitrotoluenes, nitrobenzene, PCBs, 1,4-oxathiane, thiodiglycol, p-chlorophenylmethylsulfone, p-chlorophenylmethylsulfide, and p-chlorophenylmethylsulfoxide. Surface water samples were not filtered; therefore, values presented for metals are total concentrations. As with groundwater, blank data were not available for surface water at Carroll Island; therefore, it is not possible to determine whether any chemicals were introduced in the field or the laboratory.

TABLE 8-5

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CARROLL ISLAND SERVICE AREA/DREDGE SPOILS SITE

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
Surficial Aquifer (e)			
Organic Chemicals:			
* Methylene Chloride (CH2CL2)	2 / 5	9.3 - 47.2	NA
Inorganic Chemicals:			
* Aluminum (AL)	1 / 5	2,150	100
Arsenic (AS)	2 / 5	7.3 - 8.7	100
* Barium (BA)	5 / 5	6.6 - 150	100
Bromide (BR)	2 / 5	3,410 - 4,430	100
Calcium (CA)	5 / 5	6,680 - 24,000	1,000,000
Chloride (CL)	5 / 5	13,100 - 1,500,000	1,000,000
Copper (CU)	1 / 5	17.7	100
Fluoride (F)	2 / 5	1,210 - 1,380	10,000
* Iron (FE)	5 / 5	538 - 53,100	10,000
Lead (PB)	1 / 5	13.3	100
Magnesium (MG)	5 / 5	4,330 - 48,000	1,000,000
* Manganese (MN)	5 / 5	166 - 2,500	100
Mercury (HG)	1 / 5	0.4	0.50 (f)
Nitrite/Nitrate (NIT) (g)	3 / 5	10.2 - 13.3	10,000
Potassium (K)	5 / 5	3,630 - 10,300	10,000
* Silver (AG)	2 / 5	11.8	1.0
Sodium (NA)	5 / 5	17,900 - 410,000	1,000,000
Sulfate (SO4)	5 / 5	19,000 - 128,000	1,000,000
* Thallium (TL)	1 / 5	233	1.0
Zinc (ZN)	1 / 5	49.7	100
Confined Aquifer (h)			
Inorganic Chemicals:			
Arsenic (AS)	1 / 1	4.4	100
Barium (BA)	1 / 1	18.6	100
Calcium (CA)	1 / 1	78,000	1,000,000
Chloride (CL)	1 / 1	88,000	1,000,000
Copper (CU)	1 / 1	13.4	100
Iron (FE)	1 / 1	68.9	10,000
Magnesium (MG)	1 / 1	15,100	1,000,000
* Manganese (MN)	1 / 1	202	100
Nitrite/Nitrate (NIT) (g)	1 / 1	11	10,000
Potassium (K)	1 / 1	4,100	10,000
Sodium (NA)	1 / 1	35,300	1,000,000

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Values reported for metals are dissolved concentrations.
(d) Background concentrations from Walton (1985), except as noted. Values reported are dissolved concentrations.
(e) Samples: 145, 146, 147A, 148, and 149.
(f) Background concentrations from EPA (1986a). Values reported are dissolved concentrations.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.
(h) Sample: 147B.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-6

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER AT CARROLL ISLAND
EASTERN CARROLL ISLAND

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Background Concentration (d)
Surficial Aquifer (e)			
Organic Chemicals:			
* Acetone (ACET)	1 / 42	30.9	NA
* 1,2-Dichloroethane (12DCLE)	1 / 42	1.4	NA
* PAHs [noncarcinogenic] [total]	1 / 33	16.8	NA
2-Methylnaphthalene (2MNAP)	1 / 33	2.1	NA
Naphthalene (NAP)	1 / 33	14.7	NA
* Trichlorofluoromethane (CCL3F)	1 / 42	2.1	NA
Inorganic Chemicals:			
* Aluminum (AL)	7 / 42	162 - 2,080	100
Arsenic (AS)	11 / 42	2.3 - 6.7	100
* Barium (BA)	42 / 42	10.8 - 206	100
Bromide (BR)	3 / 42	1,600 - 2,340	100
Calcium (CA)	42 / 42	3,330 - 73,000	1,000,000
Chloride (CL)	40 / 42	2,540 - 930,000	1,000,000
Chromium (CR)	1 / 42	7.1	100
Copper (CU)	24 / 42	7.2 - 49.7	100
* Iron (FE)	38 / 42	47.1 - 48,300	10,000
Lead (PB)	6 / 42	1.8 - 13.3	100
Magnesium (MG)	42 / 42	1,560 - 80,000	1,000,000
* Manganese (MN)	42 / 42	7.8 - 7,600	100
Mercury (HG)	1 / 26	0.3	0.50 (f)
Nickel (NI)	3 / 42	48.1 - 59.1	100
Nitrite/Nitrate (NIT) (g)	30 / 42	10.3 - 191	10,000
Potassium (K)	40 / 42	444 - 33,000	10,000
* Silver (AG)	7 / 42	3.6 - 12.4	1.0
Sodium (NA)	42 / 42	2,090 - 370,000	1,000,000
Sulfate (SO4)	33 / 42	14,800 - 730,000	1,000,000
* Thallium (TL)	4 / 42	104 - 169	1.0
* Zinc (ZN)	16 / 42	22.1 - 213	100
Confined Aquifer (h)			
Inorganic Chemicals:			
Arsenic (AS)	2 / 4	4.3 - 5.4	100
Barium (BA)	4 / 4	13.1 - 37	100
Calcium (CA)	4 / 4	42,000 - 85,000	1,000,000
Chloride (CL)	4 / 4	4,010 - 360,000	1,000,000
Copper (CU)	2 / 4	11.8 - 17.2	100
Iron (FE)	3 / 4	1,950 - 8,250	10,000
Lead (PB)	1 / 4	2	100
Magnesium (MG)	4 / 4	2,000 - 6,640	1,000,000
* Manganese (MN)	4 / 4	47.5 - 1,460	100
Nitrite/Nitrate (NIT) (g)	2 / 4	11.9 - 13	10,000
Potassium (K)	4 / 4	1,790 - 39,000	10,000
Sodium (NA)	4 / 4	9,950 - 160,000	1,000,000
Sulfate (SO4)	2 / 4	31,200 - 38,400	1,000,000
Zinc (ZN)	2 / 4	25.9 - 34.8	100

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Values reported for metals are dissolved concentrations.
(d) Background concentrations from Walton (1985), except as noted. Values reported are dissolved concentrations.
(e) Samples: 101-110; 112-115; 116B; 117-119; 120A; 121, 122B, 123-125; 126A&B; 127B; 128-130; 131A; 132-136; 137B; 138A; 139; 140; 144.
(f) Background concentrations from EPA (1986a). Values reported are dissolved concentrations.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.
(h) Samples: 116A, 122A, 127A, and 137A.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

The results of surface water sampling are discussed below. Few organic chemicals were detected in surface waters in any of these areas; eastern Carroll Island and the Chesapeake Bay near the Lower Island disposal site were the only areas in which they were detected. Concentrations of inorganic chemicals were compared to background concentrations from surface waters near APG. Total background concentrations were not available for all inorganic chemicals. In addition, no background samples were available from the Chesapeake Bay or Saltpeter Creek. The results of this sampling and the selection of chemicals of concern are discussed below.

8.2.2.1 EPG Dump Site

Chemicals detected in surface water at the EPG dump site are shown in Table 8-7. One surface water sample was collected from a small ponded area about 30 feet northeast of the dump site. No organic chemicals were detected in this sample although aluminum and sulfate were present in this sample at concentrations above background and were therefore selected as chemicals of potential concern.

8.2.2.2 Bengies Point Road Dump Site

Chemicals detected in surface water at the Bengies Point Road dump site are shown in Table 8-8. Samples were collected from the pond east of the site, the sluice pipe that drains the marsh area adjacent to the site, ponded water within the dump site, and the marsh east of the dump site. No organic chemicals were detected in surface waters in this area. Aluminum, antimony, beryllium, cadmium, copper, iron, manganese, nickel, silver, and sulfate were present at concentrations above background levels and were therefore selected as chemicals of potential concern. Hexadecanoic acid (palmitic acid), a tentatively identified compound, was detected at a maximum concentration of 3 µg/L as shown in Table 8-9.

8.2.2.3 Service Area

Chemicals detected in surface water at the service area are shown in Table 8-10. Surface water samples were collected from the wastewater treatment unit and from the marsh adjacent to the service area. No organic chemicals were detected in surface waters in this area. Copper, iron, and sulfate were selected as chemicals of potential concern since these chemicals were present at concentrations above background levels. A background concentration was not available for thallium, so it was conservatively selected as a chemical of potential concern. Hexadecanoic acid (palmitic acid), a tentatively identified compound, was detected at a maximum concentration of 3 µg/L in 1989. The tentatively identified compounds detected in surface water are presented in Table 8-9.

8.2.2.4 Eastern Carroll Island

Chemicals detected in surface water at eastern Carroll Island are shown in Table 8-11. Surface water samples were collected from the Test Grid #1 sump near the middle of the grid, a sluice pipe located near the Test Grid #1 sump discharge point, two ponded areas at Test Grid #2, standing water in the BZ test burn pit, the marsh east of the Lower Island disposal site, and a disposal pit at the Lower Island disposal site.

TABLE 8-7

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND EPG DUMP SITE (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Detected Concentration (d)	Range of Background Concentrations (e)
Inorganic Chemicals:			
* Aluminum (AL)	1 / 1	531	<10
Barium (BA)	1 / 1	15	74
Bromide (BR)	1 / 1	1,930	NA
Calcium (CA)	1 / 1	19,200	4,400 - 14,000
Chloride (CL)	1 / 1	710,000	12,000 - 46,000 (f)
Iron (FE)	1 / 1	960	230 - 2,700 (f)
Magnesium (MG)	1 / 1	40,000	2,000 - 7,100
Manganese (MN)	1 / 1	274	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	1 / 1	430	100 - 5,300
Potassium (K)	1 / 1	14,000	1,000 - 3,000
Sodium (NA)	1 / 1	370,000	6,700 - 21,000
* Sulfate (SO4)	1 / 1	113,000	7,000 - 21,000 (f)
Zinc (ZN)	1 / 1	29.3	75

(a) Sample: CISW5.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-8

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AT CARROLL ISLAND
BENGIES POINT ROAD DUMP SITE (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Range of Background Concentrations (e)
Inorganic Chemicals:			
* Aluminum (AL)	3 / 4	402 - 2,320	<10
* Antimony (SB)	1 / 4	147	<1
Barium (BA)	4 / 4	12.5 - 36.2	74
Bromide (BR)	1 / 4	1,780	NA
* Beryllium (BE)	1 / 4	5.9	<0.5
* Cadmium (CD)	1 / 4	11.2	<1
Calcium (CA)	4 / 4	5,240 - 16,100	4,400 - 14,000
Chloride (CL)	4 / 4	140,000 - 640,000	12,000 - 46,000 (f)
Chromium (CR)	1 / 4	20	42
* Copper (CU)	4 / 4	8.5 - 37.7	1
* Iron (FE)	4 / 4	513 - 16,400	230 - 2,700 (f)
Magnesium (MG)	4 / 4	7,850 - 35,000	2,000 - 7,100
* Manganese (MN)	4 / 4	56.5 - 1,210	100 - 700 (f)
* Nickel (NI)	1 / 4	66.3	6
Nitrite/Nitrate (NIT) (g)	1 / 4	39.6	100 - 5,300
Potassium (K)	4 / 4	3,640 - 11,000	1,000 - 3,000
* Silver (AG)	1 / 4	5.5	<1
Sodium (NA)	4 / 4	59,000 - 340,000	6,700 - 21,000
* Sulfate (SO4)	1 / 4	76,900	7,000 - 21,000 (f)
Zinc (ZN)	3 / 4	35.4 - 64.5	75

(a) Samples: CISW1, CISW2, CISW20, and CISW21.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-9

TENTATIVELY IDENTIFIED COMPOUNDS (TICs) IN CARROLL ISLAND SURFACE WATER

(Concentrations reported in ug/L)

Chemical (a)/Site	Number of Detects (b)	Range of Reported Concentrations
Bengies Point Road Dump Site		
Hexadecanoic Acid/Palmitic Acid (C16A)	2	2 - 3
Service Area		
Hexadecanoic Acid/Palmitic Acid (C16A)	1	3
Eastern Carroll Island		
Hexadecanoic Acid/Palmitic Acid (C16A)	2	2 - 4
4-Methyl-2-pentanone (DIACAL)	1	3
Pentadecanoic Acid (C15A)	1	3
Tetradecanoic Acid/Myristic Acid (C14A)	1	5
Chesapeake Bay Near Lower Island Disposal Site		
Hexadecanoic Acid/Palmitic Acid (C16A)	2	2 - 4
4-Methyl-2-pentanone (DIACAL)	1	2

(a) USATHAMA chemical codes listed in parentheses.
(b) Number of samples in which the chemical was tentatively identified.

TABLE 8-10

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND SERVICE AREA (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Range of Background Concentrations (e)
Inorganic Chemicals:			
Barium (BA)	2 / 2	21.3 - 34.3	74
Calcium (CA)	2 / 2	41,000 - 62,000	4,400 - 14,000
Chloride (CL)	1 / 2	88,000	12,000 - 46,000 (f)
* Copper (CU)	1 / 2	10.5	1
* Iron (FE)	2 / 2	334 - 6,550	230 - 2,700 (f)
Magnesium (MG)	2 / 2	7,760 - 19,500	2,000 - 7,100
Manganese (MN)	2 / 2	46.3 - 260	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	2 / 2	18 - 154	100 - 5,300
Potassium (K)	2 / 2	3,970 - 6,030	1,000 - 3,000
Sodium (NA)	2 / 2	1,860 - 55,000	6,700 - 21,000
* Sulfate (SO4)	1 / 2	30,400	7,000 - 21,000 (f)
* Thallium (TL)	1 / 2	113	NA
Zinc (ZN)	1 / 2	85.4	75

(a) Samples: CISW3 and CISW17.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-11

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND
EASTERN CARROLL ISLAND (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Range of Background Concentrations (e)
Organic Chemicals:			
* Benzene (C6H6)	1 / 7	0.6	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	1 / 7	1.2	NA
* Toluene (MEC6H5)	1 / 7	0.9	NA
Inorganic Chemicals:			
* Aluminum (AL)	4 / 7	354 - 637	<10
* Antimony (SB)	1 / 7	89.6	<1
Barium (BA)	7 / 7	11.1 - 40.6	74
* Cadmium (CD)	1 / 7	6.2	<1
Calcium (CA)	7 / 7	3,990 - 82,000	4,400 - 14,000
Chloride (CL)	7 / 7	3,300 - 71,000	12,000 - 46,000 (f)
* Copper (CU)	7 / 7	9.8 - 35.7	1
* Iron (FE)	7 / 7	338 - 4,520	230 - 2,700 (f)
Magnesium (MG)	7 / 7	2,520 - 14,400	2,000 - 7,100
Manganese (MN)	7 / 7	12.2 - 335	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	4 / 7	21 - 33.5	100 - 5,300
Potassium (K)	7 / 7	1,800 - 6,610	1,000 - 3,000
Sodium (NA)	7 / 7	2,750 - 36,900	6,700 - 21,000
* Sulfate (SO4)	4 / 7	10,100 - 32,600	7,000 - 21,000 (f)
* Zinc (ZN)	4 / 7	28.2 - 800	75

(a) Samples: CISW8, CISW9, CISW13, CISW14, CISW15, CISW16, and CISW18.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

Benzene, 1,1,2,2-tetrachloroethane, and toluene were the only organic chemicals detected in surface water at eastern Carroll Island. These chemicals were each detected in one of seven surface water samples at concentrations of 0.6 µg/L, 1.2 µg/L, and 0.9 µg/L, respectively, and were selected as chemicals of potential concern. Benzene and toluene were detected at the seasonal pond south of Test Grid #2, and 1,1,2,2-tetrachloroethane was detected in surface water from the sluice pipe from Test Grid #1. Aluminum, antimony, cadmium, copper, iron, sulfate, and zinc were present at concentrations above background levels at eastern Carroll Island and therefore were selected as chemicals of potential concern.

Four tentatively identified compounds, hexadecanoic acid (palmitic acid), 4-methyl-2-pentanone, pentadecanoic acid, and tetradecanoic acid (myristic acid), were detected at eastern Carroll Island at maximum concentrations of 4 µg/L, 3 µg/L, 3 µg/L, and 5 µg/L, respectively. The tentatively identified compounds detected in surface water are presented in Table 8-9.

8.2.2.5 Chesapeake Bay Near the Lower Island Disposal Site

Chemicals detected in the Chesapeake Bay near the Lower Island disposal site are shown in Table 8-12. Surface water samples were collected from the Chesapeake Bay southwest and south-southwest of the Lower Island disposal site. The only organic chemical detected in these surface water samples was thiodiglycol, which was detected in one of two samples at a concentration of 138 µg/L and was selected as a chemical of potential concern. Aluminum, copper, iron, silver, and sulfate were present at concentrations above background levels; therefore, these chemicals were selected as chemicals of potential concern. Two tentatively identified compounds, hexadecanoic acid (palmitic acid) and 4-methyl-2-pentanone, were detected in the Chesapeake Bay near the Lower Island disposal site at maximum concentrations of 4 µg/L and 2 µg/L, respectively (see Table 8-9).

8.2.2.6 Chesapeake Bay Near the Wind Tunnel

Chemicals detected in the Chesapeake Bay near the wind tunnel are shown in Table 8-13. One surface water sample was collected from the Chesapeake Bay south of the wind tunnel. No organic chemicals were detected in this sample. Aluminum and sulfate were present at concentrations above background levels and therefore were selected as chemicals of potential concern.

8.2.2.7 Saltpeter Creek

Chemicals detected in Saltpeter Creek are shown in Table 8-14. Samples were collected from the following locations in Saltpeter Creek: the discharge point of the drainage ditch at the EPG dump site into Saltpeter Creek, north of the BZ test burn pit and the aerial spray grid, north of the aerial spray grid, and north of the magazine area. No organic chemicals were detected in these samples. Aluminum and sulfate were selected as chemicals of potential concern in Saltpeter Creek, since these chemicals were present at concentrations above background levels.

TABLE 8-12

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND CHESAPEAKE BAY NEAR LOWER ISLAND DISPOSAL SITE (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Range of Background Concentrations (e)
Organic Chemicals:			
* Thiodiglycol (TDGCL)	1 / 2	138	NA
Inorganic Chemicals:			
* Aluminum (AL)	2 / 2	594 - 1,740	<10
Barium (BA)	2 / 2	9.4 - 18.2	74
Calcium (CA)	2 / 2	6,240 - 24,000	4,400 - 14,000
Chloride (CL)	2 / 2	190,000 - 570,000	12,000 - 46,000
* Copper (CU)	2 / 2	15.9 - 24.2	1
* Iron (FE)	2 / 2	2,450 - 5,450	230 - 2,700 (f)
Magnesium (MG)	2 / 2	10,000 - 35,000	2,000 - 7,100
Manganese (MN)	2 / 2	199 - 446	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	1 / 2	765	100 - 5,300
Potassium (K)	2 / 2	8,220 - 25,200	1,000 - 3,000
* Silver (AG)	1 / 2	5.6	<1
Sodium (NA)	2 / 2	120,000 - 275,000	6,700 - 21,000
* Sulfate (SO4)	2 / 2	10,700 - 94,900	7,000 - 21,000 (f)

(a) Samples: CISW11 and CISW12.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as chemicals of potential concern. See text.
NA = Not available..

TABLE 8-13

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND CHESAPEAKE BAY NEAR THE WIND TUNNEL (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Detected Concentration (d)	Range of Background Concentrations (e)
Inorganic Chemicals:			
* Aluminum (AL)	1 / 1	676	<10
Barium (BA)	1 / 1	14.3	74
Calcium (CA)	1 / 1	17,400	4,400 - 14,000
Chloride (CL)	1 / 1	440,000	12,000 - 46,000 (f)
Iron (FE)	1 / 1	972	230 - 2,700 (f)
Magnesium (MG)	1 / 1	29,000	2,000 - 7,100
Manganese (MN)	1 / 1	127	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	1 / 1	880	100 - 5,300
Potassium (K)	1 / 1	10,500	1,000 - 3,000
Sodium (NA)	1 / 1	220,000	6,700 - 21,000
* Sulfate (SO4)	1 / 1	73,900	7,000 - 21,000 (f)

(a) Sample: CISW10
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 8-14

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AT CARROLL ISLAND SALTPETER CREEK (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Range of Background Concentrations (e)
Inorganic Chemicals:			
* Aluminum (AL)	4 / 4	384 - 866	<10
Barium (BA)	4 / 4	14.7 - 18.2	74
Bromide (BR)	4 / 4	1,470 - 2,090	NA
Calcium (CA)	4 / 4	15,800 - 17,800	4,400 - 14,000
Chloride (CL)	4 / 4	600,000 - 770,000	12,000 - 46,000 (f)
Iron (FE)	4 / 4	551 - 1,290	230 - 2,700 (f)
Magnesium (MG)	4 / 4	38,000 - 47,000	2,000 - 7,100
Manganese (MN)	4 / 4	110 - 155	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	4 / 4	740 - 880	100 - 5,300
Potassium (K)	4 / 4	11,000 - 16,000	1,000 - 3,000
Sodium (NA)	4 / 4	300,000 - 370,000	6,700 - 21,000
* Sulfate (SO4)	4 / 4	92,100 - 108,000	7,000 - 21,000 (f)

(a) Samples: CISW4, CISW6, CISW7, and CISW19.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Total concentrations reported.
(e) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

8.2.3 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Chemicals of potential concern in groundwater and surface water at Carroll Island are summarized in Table 8-15 and 8-16, respectively. Inorganic chemicals are the predominant chemicals of potential concern in groundwater and surface water, although there is some uncertainty associated with this determination because no site-specific background concentration data were available for these naturally occurring chemicals. As can be seen from these data, virtually no organic chemicals were detected in the surficial aquifer and none were detected in the confined aquifer. Low levels of volatile organic chemicals were detected in surface water at eastern Carroll Island. Thiodiglycol was detected in the Chesapeake Bay near the Lower Island disposal site. Chemicals of potential concern could not be selected for soil/sediment, because data are not available at this time.

In addition to the chemicals of potential concern selected for groundwater and surface water using the available sampling data, other chemicals are likely to be present at Carroll Island and may be of potential concern regarding possible exposures and risks. Table 8-17 summarizes additional chemicals potentially of concern for Carroll Island that were not included in any of the chemical analyses. The chemicals listed are those that have the potential to be present in the greatest quantities based on historical information. Other chemicals could be present in smaller quantities at Carroll Island and therefore could also contribute to potential exposures and risks. For example, degradation products of adamsite and chloroacetophenone are possibly present in groundwater at eastern Carroll Island. However, these parent products are generally resistant to degradation, and therefore their breakdown products are likely present in small quantities.

8.3 HUMAN HEALTH RISK ASSESSMENT

This section addresses the potential human health risks associated with Carroll Island in the absence of remedial actions. This human health risk assessment is divided into three principal sections. Section 8.3.1 evaluates and provides estimates of potential human exposures for the chemicals of potential concern at the site. Section 8.3.2 summarizes relevant toxicity information for the chemicals of potential concern. Section 8.3.3 provides quantitative and qualitative estimates of human health risks.

8.3.1 EXPOSURE ASSESSMENT

This section identifies the pathways by which human populations may be exposed to chemicals of potential concern at or originating from Carroll Island and selects pathways for further evaluation. Only complete pathways were selected for further evaluation (see Chapter 4 for a definition of a complete pathway). Evaluations of exposures may be quantitative or qualitative depending upon several factors, including the probability of exposure, the potential magnitude of exposure, and the availability of data to support quantitative evaluations. Exposure point concentrations and daily intakes were estimated for all pathways selected for quantitative evaluation.

This exposure assessment is organized into three principal sections. Section 8.3.1.1 discusses potential exposure pathways under current land-use conditions, and Section 8.3.1.2 discusses those potentially occurring under hypothetical future land-use conditions. Section 8.3.1.3 presents estimates of potential human exposures for those pathways selected for quantitative evaluation.

TABLE 8-15

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER FOR CARROLL ISLAND

Chemical (a)	EPG Dump Site	Bengies Point Road Dump Site		Service Area/ Dredge Spoils Area		Eastern Carroll Island	
	Surficial Aquifer	Surficial Aquifer	Confined Aquifer	Surficial Aquifer	Confined Aquifer	Surficial Aquifer	Confined Aquifer
Organic Chemicals:							
Acetone (ACET)						X	
1,2-Dichloroethane (12DCLE)						X	
Methylene Chloride (2CH2CL2)		X		X			
PAHs [noncarcinogenic]						X	
2-Methylnaphthalene (2MNAP)						X	
Naphthalene (NAP)						X	
Trichlorofluoromethane (CCL3F)						X	
Inorganic Chemicals:							
Aluminum (AL)	X	X		X		X	
Barium (BA)		X		X		X	
Iron (FE)	X	X		X		X	
Manganese (MN)	X	X	X	X	X	X	X
Silver (AG)	X	X		X		X	
Thallium (TL)	X	X		X		X	
Zinc (ZN)	X					X	

(a) USATHAMA chemical codes listed in parentheses.

(= Selected as a chemical of potential concern.

Note: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium, (2) it was not included in the analyses, or (3) it was detected at background concentrations (inorganic chemicals only). See text for this information.

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TABLE 8-16

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER FOR CARROLL ISLAND

Chemical (a)	EPG Dump Site	Bengies Point Road Dump Site	Service Area	Eastern Carroll Island	Chesapeake Bay Near Lower Island Disposal Site	Chesapeake Bay Near the Wind Tunnel	Saltpeter Creek
Organic Chemicals:							
Benzene (C6H6)				X			
1,1,2,2-Tetrachloroethane (TCLEA)				X			
Toluene (MEC6H5)				X			
Thiodiglycol (TDGCL)					X		
Inorganic Chemicals:							
Aluminum (AL)	X	X		X	X	X	X
Antimony (SB)		X		X			
Beryllium (BE)		X					
Cadmium (CD)		X		X			
Copper (CU)		X	X	X	X		
Iron (FE)		X	X	X	X		
Manganese (MN)		X					
Nickel (NI)		X					
Silver (AG)		X			X		
Sulfate (SO4)	X	X	X	X	X	X	X
Thallium (TL)			X				
Zinc (ZN)				X			

(a) USATHAMA chemical codes listed in parentheses.

X = Selected as a chemical of potential concern.

Note: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium, (2) it was not included in the analyses, or (3) it was detected at background concentrations (inorganic chemicals only). See text for this information.

TABLE 8-17

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT CARROLL ISLAND (a)

Site	Group	Chemical	Comments
EPG Dump Site	Decontaminating Agents	Supertropical Bleach (STB)	Drums of STB are visible at the surface of this site. STB is a strong oxidizing agent which will react violently with organic matter. Release could cause pH elevation and potential chlorination of organic chemicals which may be present. Acute hazards could potentially occur if these drums were disturbed.
Eastern Carroll Island	Lethal Chemical Agents	VX Distilled Mustard (HD)	Large quantities of VX were tested at eastern Carroll Island. VX is moderately persistent and is mobile in surface water and groundwater. HD can persis in soil by forming an oxide coating. HD will rapidly hydrolyze in water to thiodiglycol. Thiodiglycol was detected in the Chesapeake Bay near the Lower Island disposal site.
	Incapacitating Agents	Adamsite (DM) Chloroacetophenone (CN)	Large quantities of CN and DM were tested at eastern Carroll Island. DM can persist in the environment by forming an oxide coating as a result of hydrolysis. DM has a low mobility and a high persistence in soil, particularly when disposed of in large quantities. CN has a solubility in water comparable to several chlorinated volatile organic chemicals, is not appreciably adsorbed by soil, and is relatively stable to hydrolysis. CN can therefore be mobile in the subsurface.

(a) Based on historical information. Chemicals listed are those potentially present in the greatest quantities. A large number of other chemicals could be present in smaller quantities at Carroll Island.

8.3.1.1 Potential Exposure Pathways Under Current Land-Use Conditions

The only current use of Carroll Island is for recreational hunting and trapping by active and retired civilian and military personnel and their immediate family members and sponsored guests. Hunting occurs in designated areas across the entire island. Trapping is allowed on portions of the western half of Carroll Island. The Bengies Point Road dump site is the only testing or disposal area within the portion of Carroll Island where trapping is allowed.

Fishing from a boat is allowed in the waters around Carroll Island. The bridge to Carroll Island from the mainland is a very popular fishing spot. A fence with a gate just past the end of the bridge restricts access to the island. There are no docks or piers on Carroll Island, and there are no areas at Carroll Island approved for recreational fishing or crabbing from the shoreline.

Carroll Island does not currently have a source of potable water. There are two wells that were used for water supply during active military operations at Carroll Island. These wells are not currently in use, but they have not been permanently closed. During the period of time when Carroll Island was actively used for chemical agent testing, well water was used for nonpotable uses, and drinking water was brought in from Edgewood Area, because of the bad taste of the groundwater at Carroll Island. It is not known if groundwater at Carroll Island was ever used for drinking water during the period of chemical agent testing.

The Tipple Power Plant is located immediately west of Carroll Island across the bridge on the mainland. The area on the other side of the power plant is not heavily developed or populated. Most of the houses in this area obtain drinking water from wells. The power plant and a nursery are the only two commercial groundwater users in the vicinity of Carroll Island. The power plant has an aquaculture facility that draws water from a well at a maximum rate of approximately 150 gallons per minute (USGS 1990). Groundwater and surface water is added to the water in the fish tanks for cooling purposes. The nursery, which is located northwest of Carroll Island between Dundee Creek and Saltpeter Creek, uses groundwater during the growing season to water plants and trees.

8.3.1.1.1 Potential Long-Term Exposure Pathways Under Current Land-Use Conditions

Table 8-18 summarizes the pathways by which humans could be exposed to chemicals at or originating from Carroll Island under current land-use conditions. Potential exposure pathways are discussed below by exposure medium.

Groundwater. Currently, there are no uses of groundwater at Carroll Island, and downgradient users are unlikely to be affected by groundwater migrating from the site. The surficial aquifer at Carroll Island discharges into the surrounding surface water and, therefore, does not impact off-post drinking water wells. The confined deep aquifer could be hydraulically connected to groundwater on the mainland. If groundwater in this deeper aquifer flows towards the mainland (currently unknown), contamination of off-post wells could result. However, there is very little (if any) contamination in the deeper confined aquifer. No organic chemicals were detected in this aquifer, and the only inorganic chemical potentially present above background concentrations is manganese. Even if groundwater transport to off-post wells was occurring, the concentrations of manganese reaching off-post wells would be significantly diluted. For these reasons, significant contamination of off-post wells via groundwater transport from Carroll Island is unlikely. Therefore, ingestion of groundwater by off-post residents was not evaluated in this assessment.

TABLE 8-18

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT CARROLL ISLAND

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Groundwater (Surficial Aquifer)	There is no potential for human exposure to surficial aquifer groundwater from Carroll Island because there is currently no use of groundwater at the site and because surficial groundwater likely discharges to surface water surrounding the island. Therefore, this groundwater would not contaminate off-post drinking water wells.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Groundwater (Confined Aquifer)	The confined aquifer currently is not used at Carroll Island. However, this aquifer could be hydraulically connected to the mainland and chemicals could be transported to off-post wells. Exposures could occur in off-post residents drinking from these wells.	Negligible. Contamination in the confined aquifer is limited. Manganese was the only chemical of potential concern selected for the deeper aquifer and its presence could be related to background conditions. Even if off-post transport is occurring, the concentrations of manganese reaching off-post wells would be significantly diluted.	Poor. Off-post groundwater data not collected and very few data available on the direction of groundwater flow from Carroll Island to off-post areas.	None, due to low potential for exposure and lack of data.
Surface Water and Sediment	Dermal contact with chemicals of potential concern in surface water/sediment by hunters and trappers.	Negligible. Hunting is not expected to result in significant contact with surface water or sediment. Trappers could contact surface water, but the chemicals detected in surface water where trapping takes place are not dermally absorbed to any appreciable extent. The potential for sediment exposures is unknown.	Poor. Only four samples collected from the area where trapping occurs. No sediment data available.	None, due to low potential for exposure and lack of data.
Surface Soil	Dermal contact and/or incidental ingestion of surface soil by hunters and trappers.	Negligible. Since Carroll Island is well vegetated, hunters and trappers are not expected to dermally contact surface soil to any significant extent.	Poor. Data not available at this time.	None, due to low potential for exposure and lack of data.
Soil/ Eastern Carroll Island	Acute Hazards: Hunters encountering mustard or other chemical agents or drums of supertropical bleach resulting in dermal and inhalation exposures.	Moderate to high. Although eastern Carroll Island is used infrequently by hunters, the potential exists for high exposures if agents or drums of bleach are encountered and disturbed.	Poor. No data available concerning the quantities of chemical agents present in surface soils of the area.	Qualitative.

See footnotes on the following page.

TABLE 8-18 (Continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT CARROLL ISLAND

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Subsurface Soil	None. Although subsurface soils are likely to be contaminated as a result of past waste disposal, no activities that involve contact with subsurface soil (e.g., excavation) take place at Carroll Island.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Air	Inhalation of vapors from surface soil, surface water, and subsurface wastes or dust generated from surface soil by hunters and trappers.	Negligible. Migration of contaminants by wind entrainment of dust particles is unlikely to be important because the island is completely vegetated and likely has a high soil moisture content. Volatilization from surface water is unlikely to be important, since the only volatile chemicals detected in surface water were detected infrequently at low concentrations. Although no data area available on chemical concentrations in subsurface soil and wastes, potential emissions from these sources are not likely to result in significant exposures due to dilution and dispersion from possible emissions sources and the relatively infrequent use of Carroll Island by hunters and trappers.	Poor. Air and subsurface waste data not collected and soil data not available at this time.	None, due to low potential for exposure and lack of data.
Fish and Crab	Ingestion by local fishermen of fish/crab that have accumulated chemicals from surface waters surrounding Carroll Island.	Negligible, due to types of chemicals present in surface water around the eastern perimeter of Carroll Island. Site-related chemicals are not expected to be present in surface water around the western perimeter of Carroll Island, although no data are available for this area.	Poor. No fish/crab samples collected. Surface water and sediment samples not collected around the western perimeter of Carroll Island and the results of the limited sediment sampling around eastern Carroll Island not available at this time.	None, due to types of chemicals present or expected to be present in the surface water surrounding Carroll Island.
Game/ Eastern Carroll Island	Ingestion by hunters of upland game/early migratory birds that have accumulated chemicals from Carroll Island.	Negligible. Types of chemicals present in surface water are not expected to bioaccumulate extensively in terrestrial wildlife.	Poor. Soil/sediment results not available at this time to assess any potential accumulation in wildlife.	None, due to types of chemicals present in surface water, and lack of soil/sediment data.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.
NA = Not applicable.

Surface Water/Sediment. Carroll Island is currently used only by hunters and trappers. Hunting is not expected to result in significant contact with surface water or sediment because it occurs infrequently and because of the nature of hunting activities. Trapping occurs more frequently and is more likely to involve contact with surface waters (e.g., while setting traps). Trappers are unlikely to be significantly exposed to chemicals in surface water, however, because the chemicals of potential concern detected in surface waters in the area where trapping takes place (the Bengies Point Road dump site) are inorganic chemicals, which are not dermally absorbed to any significant extent. The potential for sediment exposure is unknown, because no sediment sample data are currently available. However, trapping is not expected to result in extensive contact with sediments. Therefore, dermal contact with surface water or sediment by hunters and trappers was not evaluated.

Surface Soil. As a result of chemical agent tests at eastern Carroll Island from 1949 to 1972, residual surface contamination may be present in many areas. Chemicals that may be present in surface soil include chemical agents, breakdown products, volatile and semivolatile organic chemicals, pesticides, and inorganic chemicals (soil samples have been collected but are not available at this time). Because Carroll Island is well vegetated, hunters and trappers (the only users of thie island) are not expected to contact surface soil to any significant extent. This pathway was therefore not evaluated.

Subsurface Soil. Although subsurface soils are likely to be contaminated as a result of past waste disposal, no activities that involve soil disturbance (e.g., excavation) take place at Carroll Island under current land-use conditions. Therefore, direct exposure to subsurface soil was not evaluated.

Air. Hunters and trappers are the only populations that could potentially be exposed to any airborne contaminants at Carroll Island. Air contaminants could be present as a result of volatilization of chemicals from the subsurface environment (i.e., soil, wastes, or groundwater) or surface waters or from dust generated from surface soil containing chemicals of potential concern. Although no data are available on chemical concentrations in surface soil, migration of contaminants by wind entrainment of dust particles is unlikely to be an important transport process at Carroll Island; because the area is completely vegetated and the soil is likely to have a high moisture content. Volatilization from surface water also is unlikely to be important, given that the only volatile chemicals detected in surface water were detected infrequently and at low concentrations. No data are available on chemical concentrations in subsurface soil or subsurface waste, and therefore potential emissions from these sources is unknown. However, even if chemicals are volatilizing from the subsurface environment (including groundwater), such emissions are not likely to result in significant exposures when factors such as dilution and dispersion are considered. (Hunters or trappers are not likely to remain directly above an emission source for any significant period of time.) Furthermore, the relatively infrequent and short-duration use of Carroll Island by hunters minimizes the potential for significant inhalation exposures. For these and the other reasons stated above, inhalation exposures at Carroll Island are not likely to be significant, and were not selected for evaluation.

Fish/Crabs. Persons fishing or crabbing from boats in the waters around Carroll Island and from the bridge to Carroll Island could be exposed to chemicals in surface water via ingestion of fish or crabs that have accumulated these chemicals. Based on the available data, bioaccumulation is not expected to be significant along the shoreline of the eastern half of Carroll Island, because none of the organic and inorganic chemicals detected in surface water in this area is expected to accumulate appreciably in fish or crabs. Surface water and sediment samples were not collected around the perimeter of the western half of Carroll Island, so this pathway cannot be evaluated for fishing in this area. However, surface water around the western perimeter of Carroll Island is unlikely to have been affected by activities on Carroll Island. Ingestion of fish or crabs was therefore not selected for evaluation.

Game. The only hunting currently allowed at Carroll Island is upland game/early migratory bird hunting. Hunting occurs infrequently because of the distance from the industrial/residential sector of the Edgewood Area (approximately 17 miles) by road. Surface soil and sediment results are not available at this time to assess any potential accumulation in wildlife through their contact with soils. Nevertheless, ingestion of game that has accumulated chemicals from Carroll Island was not evaluated in this assessment, principally because none of the chemicals detected in surface water at Carroll Island tend to bioaccumulate extensively in terrestrial wildlife and because hunting is infrequent.

8.3.1.1.2 Potential Acute Hazards Under Current Land-Use Conditions

It is possible that mustard is present near the Lower Island disposal site, given that thiodiglycol, a hydrolysis product of mustard, was detected in the surface water sample taken from this area. Furthermore, residual surface contamination could occur in many areas of eastern Carroll Island, given that this area was used for chemical agent testing from 1949 to 1972. Chemicals that could be present in surface soil and that are of concern with respect to acute human health hazards include lethal chemical agents and incapacitating agents. Acute hazards also may be associated with drums of supertropical bleach at the EPG dump site. Persons hunting in eastern Carroll Island (no trapping occurs here) are thus at risk of acute exposures and hazards if any of these materials is encountered. Although hunters use eastern Carroll Island infrequently, serious injury could result if they encounter mustard at the Lower Island disposal site or drums of supertropical bleach at the EPG dump site. These acute exposure pathways were therefore evaluated.

8.3.1.2 Potential Exposure Pathways Under Future Land-Use Conditions

Use of Carroll Island could change in the future. The most likely additional uses would be for training or testing or for ordnance disposal. If land use changes in the future, workers could be exposed to chemicals present in groundwater, surface soil, subsurface soil, and air.

Worker exposure to chemicals in surface water or sediment is not likely, because workers are unlikely to wade or swim in surface waters of the area.

Direct contact with chemicals in surface soil or subsurface soils (during excavation) could occur, but no data are available by which to evaluate this pathway. Worker inhalation exposures also could occur but are likely to be negligible for the reasons outlined previously for hunters under current land-use conditions.

Although the future development of the groundwater beneath Carroll Island for a drinking water supply is considered unlikely due to its naturally poor taste, it does meet the criteria for a potential drinking water resource (as discussed in Chapter 4) and will be evaluated as such in this assessment. Worker exposures will be evaluated because workers are the only population that might use groundwater at Carroll Island.

Ingestion of groundwater by future workers was quantitatively evaluated for the EPG dump site, the Bengies Point Road dump site, the service area/dredge spoils site, and eastern Carroll Island. Dermal contact and inhalation of chemicals in groundwater by future workers was evaluated in areas where volatile organic chemicals were detected. The surficial aquifer groundwater at the EPG dump site and the confined aquifer groundwater were not evaluated for dermal contact and inhalation, because no organic chemicals were detected in these areas.

Workers also could experience acute hazards if unexploded ordnance were encountered during construction or excavation activities, resulting in detonation of ordnance. White phosphorus and high-explosive rounds were tested at eastern Carroll Island in the late 1940s. Information concerning the quantity of unexploded ordnance potentially at eastern Carroll Island is not available. Currently, the APG safety office requires a magnetometer survey prior to any excavation at APG. Assuming that this requirement remains in force, disturbance of unexploded ordnance as a result of excavation would probably be unlikely to occur. Nevertheless, this pathway was evaluated because serious injury could result if unexploded ordnance was disturbed. This pathway was evaluated qualitatively.

Future workers may also encounter mustard at the Lower Island disposal site or disturb drums of supertropical bleach at the EPG dump site. However, the hazards associated with this event would be identical to those discussed for hunters under current land-use conditions, and this pathway was not evaluated in this assessment. Table 8-19 summarizes the pathways by which workers could be exposed to chemicals at or originating from Carroll Island under future land-use conditions.

8.3.1.3 Quantification of Exposure

The only exposure pathway selected for quantitative evaluation is ingestion of groundwater by future workers at the EPG dump site, the Bengies Point Road dump site, the service area/dredge spoils site, and eastern Carroll Island. To assess exposure quantitatively, the chronic daily intake (CDI) of each chemical of potential concern was estimated for the reasonable maximum exposure (RME) case (EPA 1989a), as described in Chapter 4. To evaluate groundwater ingestion exposures, future workers at Carroll Island were assumed to drink 1 liter of water 241 days per year (assuming 5 work days a week, 9 holidays, and 2 weeks vacation per year) for 20 years. Twenty years was chosen as an upper-bound estimate of the amount of time a civilian worker might stay in the same job at APG. In addition, future workers were assumed to weigh 70 kg (EPA 1989b) and live for 70 years (EPA 1989a).

The methodology for estimating exposure point concentrations for the RME case is summarized in Chapter 4. Exposure point concentrations of chemicals of potential concern in groundwater at Carroll Island are presented in Tables 8-20 through 8-23. The exposure concentration is the lower value of the 95% upper confidence limit on the arithmetic mean concentrations or the maximum detected value (EPA 1989a).

Drinking water exposures were calculated using the following equation:

$$CDI = (C_w * IR * EF * ED * Z) / (BW * DY * YL) \qquad \text{(Eq. 1)}$$

where:

CDI = chronic daily intake (mg/kg-day);

C_w = exposure point concentration in groundwater (μg/L);

IR = ingestion rate (1 liter/day);

TABLE 8-19

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER FUTURE LAND-USE CONDITIONS AT CARROLL ISLAND

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Groundwater (Surficial Aquifer)/ EPG Dump Site	Ingestion of groundwater by future workers.	High, due to types of chemicals present and possible use of groundwater for drinking water.	Poor. Data available only from 3 wells in this area.	Quantitative.
Groundwater (Surficial Aquifer)/ - Bengies Point Road Dump Site - Service Area/ Dredge Spoils Site - Eastern Carroll Island	Ingestion of, dermal contact with, and inhalation of chemicals in groundwater by future workers.	Ingestion: High, due to types of chemicals present and possible use of groundwater for drinking water. Dermal contact & inhalation: Moderate, due to types of chemicals present.	Poor to moderate. Data available from only five wells in the Bengies Point Dump site and the Service Area site. Data available from 42 wells for all of eastern Carroll Island.	Ingestion: Quantitative. Dermal contact & inhalation: Qualitative.
Groundwater (Confined Aquifer)/ - Bengies Point Road Dump Site - Service Area/ Dredge Spoils Site - Eastern Carroll Island	Ingestion of groundwater by future workers.	Moderate, due to presence of manganese and possible use of groundwater for drinking water.	Poor. Data available from signle wells at Bengies Point or Service Area and from only 4 wells across eastern Carroll Island.	Quantitative.
Surface Soil	Dermal contact and/or incidental ingestion of surface soil by future workers.	Unknown, due to lack of surface soil data.	Poor. Data not available at this time.	None, due to lack of data.
Subsurface Soil	Dermal contact and/or incidental ingestion of soil by future workers during excavation.	Unknown, due to lack of information concerning quantities of chemicals in the subsurface environment.	Poor. Data not available.	None, due to lack of data.
Air	Inhalation of vapors from surface soil, surface water, and subsurface wastes or dust generated from surface soil by workers.	Negligible. Migration of contaminants by wind entrainment of dust particles is unlikely to be important because the island is completely vegetated and likely has a high soil moisture content. Volatilization from surface water is unlikely to be important, since the only volatile chemicals detected in surface water were detected infrequently at low concentrations. Although no data area available on chemical concentrations in subsurface soil and wastes, potential emissions from these sources are not likely to result in significant exposures due to dilution and dispersion from possible emissions sources.	Poor. Data on potential emission sources not adequate or not available for modelling potential air releases.	None, due to lack of data.

See footnotes on the following page.

TABLE 8-19 (Continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER FUTURE LAND-USE CONDITIONS AT CARROLL ISLAND

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Soil/ Eastern Carroll Island	Acute Hazards: Future workers encountering unexploded ordnances during excavation.	High. If WP and HE rounds are encountered, serious injury may result.	Poor. Magnetometer surveys only conducted within and around most of the disposal areas and all of the later test areas.	Qualitative.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.
NA = Not applicable.

TABLE 8-20

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CARROLL ISLAND EPG DUMP SITE

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Surficial Aquifer				
Inorganic Chemicals:				
Aluminum (AL)	13,000	1.1E+47	23,200	23,200
Iron (FE)	32,000	260,000	39,400	39,400
Manganese (MN)	820	3,400	999	999
Silver (AG)	6.7	2,600	10.1	10.1
Thallium (TL)	150	480,000	251	251
Zinc (ZN)	120	6.2E+12	179	179

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

TABLE 8-21

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CARROLL ISLAND BENGIES POINT ROAD DUMP SITE

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Surficial Aquifer				
Organic Chemicals:				
Methylene Chloride (CH2CL2)	10	7,700	47.2	47.2
Inorganic Chemicals:				
Aluminum (AL)	1,600	4,700,000	5,060	5,060
Barium (BA)	100	800	274	274
Iron (FE)	34,000	5.6E+18	83,000	83,000
Manganese (MN)	900	3,600	1,900	1,900
Silver (AG)	11	260	25.3	25.3
Thallium (TL)	130	720	259	259
Confined Aquifer				
Inorganic Chemicals:				
Manganese (MN)	NA	NA	686	686

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

NA = Not applicable; single sample.

TABLE 8-22

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CARROLL ISLAND SERVICE AREA/DREDGE SPOILS SITE

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Surficial Aquifer				
Organic Chemicals:				
Methylene Chloride (CH2CL2)	12	14,000	47.2	47.2
Inorganic Chemicals:				
Aluminum (AL)	490	89,000	2,150	2,150
Barium (BA)	51	1,300	150	150
Iron (FE)	26,000	340,000,000	53,100	53,100
Manganese (MN)	940	12,000	2,500	2,500
Silver (AG)	6.1	48	11.8	11.8
Thallium (TL)	85	310	233	233
Confined Aquifer				
Inorganic Chemicals:				
Manganese (MN)	NA	NA	202	202

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

NA = Not applicable; single sample.

TABLE 8-23

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT CARROLL ISLAND
EASTERN CARROLL ISLAND

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Surficial Aquifer				
Organic Chemicals:				
Acetone (ACET)	7.1	7.4	30.9	7.4
1,2-Dichloroethane (12DCLE)	0.3	0.3	1.4	0.3
PAHs [noncarcinogenic] [Total]	1.6	1.6	16.8	1.6
2-Methylnaphthalene (2MNAP)	0.9	0.9	2.1	0.9
Naphthalene (NAP)	0.7	0.5	14.7	0.5
Trichloroflouromethane (CCL3F)	0.7	0.8	2.1	0.8
Inorganic Chemicals:				
Aluminum (AL)	160	160	2,080	160
Barium (BA)	51	62	206	62
Iron (FE)	8,400	160,000	48,300	48,300
Manganese (MN)	750	2,000	7,600	2,000
Silver (AG)	3.3	3.6	12.4	3.6
Thallium (TL)	50	55	169	55
Zinc (ZN)	35	44	213	44
Confined Aquifer				
Inorganic Chemicals:				
Manganese (MN)	670	5,300,000	1,460	1,460

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

EF = exposure frequency (241 days/year);

ED = exposure duration (20 years);

Z = conversion factor (mg/1,000 ug);

BW = body weight over the period of exposure (70 kg);

DY = days in a year (365 days/year); and

YL = period over which risk is being estimated (a lifetime [70 years] for potential carcinogens and the period of exposure [20 years] for noncarcinogens) (years).

CDIs calculated using these exposure assumptions were presented in Tables 8-24 to 8-27.

8.3.2 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria has been described in Chapter 4 to provide the analytical framework for the characterization of human health impacts. The health effects criteria that were used to derive estimates of risk for future workers ingesting groundwater are presented in Table 8-28. No oral toxicity criteria are available for aluminum and iron to derive estimates of risk for future workers ingesting groundwater. Therefore, potential risks associated with exposure to these chemicals were not quantitatively evaluated. However, complete toxicity summaries of these chemicals are provided in Appendix B.

No toxicity criteria are provided in this section for the other chemicals of concern potentially present at Carroll Island (see Table 8-17). Toxicity summaries are provided for these chemicals in Appendix B.

8.3.3 RISK CHARACTERIZATION

In this section, the human health risks potentially associated with Carroll Island are evaluated. Risks were evaluated either quantitatively or qualitatively. To quantitatively assess risks, the CDIs calculated in Section 8.3.1 were combined with the health effects criteria presented in Section 8.3.2. Potential risks under current land-use conditions are presented in Section 8.3.3.1, and potential risks under future land-use conditions are presented in Section 8.3.3.2.

8.3.3.1 Potential Risks Under Current Land-Use Conditions

The only pathways selected for evaluation under current land-use conditions were acute exposures: (1) hunters encountering mustard near the Lower Island disposal site, (2) hunters at eastern Carroll Island encountering lethal chemical agents and incapacitating agents potentially present in surface soil/sediment, and (3) hunters and trappers disturbing drums of supertropical bleach at the EPG dump site. These pathways were selected for qualitative evaluation.

TABLE 8-24

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE CARROLL ISLAND EPG DUMP SITE (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Noncarcinogenic Effects		
Surficial Aquifer:		
Manganese (MN)	999	9.4E-03
Silver (AG)	10.1	9.5E-05
Thallium (TL)	251	2.4E-03
Zinc (ZN)	179	1.7E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.
(b) USATHAMA chemical codes listed in parentheses.
(c) See text for exposure assumptions.

TABLE 8-25

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE CARROLL ISLAND BENGIES POINT ROAD DUMP SITE (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Surficial Aquifer:		
Methylene Chloride (CH2CL2)	47.2	1.3E-04
Chemicals Exhibiting Noncarcinogenic Effects		
Surficial Aquifer:		
Methylene Chloride (CH2CL2)	47.2	4.5E-04
Barium (BA)	274	2.6E-03
Manganese (MN)	1,900	1.8E-02
Silver (AG)	25.3	2.4E-04
Thallium (TL)	259	2.4E-03
Confined Aquifer:		
Manganese (MN)	686	6.5E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.
(b) USATHAMA chemical codes listed in parentheses.
(c) See text for exposure assumptions.

TABLE 8-26

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE CARROLL ISLAND SERVICE AREA/DREDGE SPOILS SITE (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Surficial Aquifer:		
Methylene Chloride (CH2CL2)	47.2	1.3E-04
Chemicals Exhibiting Noncarcinogenic Effects		
Surficial Aquifer:		
Methylene Chloride (CH2CL2)	47.2	4.5E-04
Barium (BA)	150	1.4E-03
Manganese (MN)	2,500	2.4E-02
Silver (AG)	11.8	1.1E-04
Thallium (TL)	233	2.2E-03
Confined Aquifer:		
Manganese (MN)	202	1.9E-03

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.

(b) USATHAMA chemical codes listed in parentheses.

(c) See text for exposure assumptions.

TABLE 8-27

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT CARROLL ISLAND EASTERN CARROLL ISLAND (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Surficial Aquifer:		
1,2-Dichloroethane (12DCLE)	0.3	8.1E-07
Chemicals Exhibiting Noncarcinogenic Effects		
Surficial Aquifer:		
Acetone (ACET)	7.4	7.0E-05
PAHs [Noncarcinogenic, total]	1.6	1.5E-05
Trichlorofluoromethane (CCL3F)	0.8	7.5E-06
Barium (BA)	62	5.8E-04
Manganese (MN)	2,000	1.9E-02
Silver (AG)	3.6	3.4E-05
Thallium (TL)	55	5.2E-04
Zinc (ZN)	44	4.2E-04
Confined Aquifer:		
Manganese (MN)	1,460	1.4E-02

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.
(b) USATHAMA chemical codes listed in parentheses.
(c) See text for exposure assumptions.

TABLE 8-28

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT CARROLL ISLAND

Chemical	Chronic Reference Dose (mg/kg/day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg/day)-1	EPA Weight of Evidence Classification (c)	Slope Fact Sourc
Organic Chemicals:							
Acetone	1.00E-01	1,000	Kidney/Liver	IRIS	--	D	IRIS
1,2-Dichloroethane	--	--	--	IRIS	9.10E-02	B2	IRIS
Methylene Chloride	6.00E-02	100	Liver	IRIS	7.50E-03	B2	IRIS
PAHs	4.00E-03 (d)	10,000	Eye	HEAST	1.15E+01 (e)	B2	HEA
Trichlorofluoromethane	3.00E-01	1,000	Mortality	IRIS	--	--	--
Inorganic Chemicals:							
Aluminum	--	--	--	--	--	--	--
Barium	7.00E-02	3	Cardiovascular System	IRIS	--	--	IRIS
Iron	--	--	--	HEAST	--	--	--
Manganese	1.00E-01	1	CNS	IRIS	--	--	--
Silver	3.00E-03	2	Skin (Argyria)	IRIS	--	D	IRIS
Thallium	7.00E-05	3,000	Blood/Hair	HEAST	--	--	HEAS
Zinc	2.00E-01	10	Blood (Anemia)	HEAST	--	--	HEAS

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference do generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target org If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the c is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; ar
[D] = Not classified as to human carcinogenicity.

(d) The RfD for PAHs is for naphthalene, which was chosen as a surrogate for all noncarcinogenic PAHs.

(e) The slope factor for PAHs is for benzo[a]pyrene, which was chosen as a surrogate for all carcinogenic PAHs.

NOTE: IRIS = Integrated Risk Information System - December 1, 1990
HEA = Health Effects Assessment Document
HEAST = Health Effects Assessment Summary Tables - July 1, 1990
-- = No information available.

Hunters or trappers disturbing drums of supertropical bleach at the EPG dump site are at risk of burns. Hunters who encounter mustard at the Lower Island disposal site may suffer incapacitating or lethal effects from exposure to mustard. Information concerning the quantity of mustard present at the Lower Island disposal site is not available.

Hunters at eastern Carroll Island could also encounter VX (a nerve agent), adamsite, and chloroacetophenone in surface soil/sediment. Information concerning the possible concentrations of these lethal chemical agents and incapacitating agents at eastern Carroll Island is not available. Exposure to VX could result in acute injuries to the eyes, skin, respiratory system or death. Exposure to adamsite causes irritation of the eyes and mucous membranes, severe headache, acute pain and tightness in the chest, nausea, and vomiting. Chloroacetophenone is an irritant to the upper respiratory passages.

8.3.3.2 Potential Risks Under Future Land-Use Conditions

The only future land-use pathways selected for evaluation were (1) ingestion of groundwater by future workers, (2) dermal contact and inhalation of chemicals in groundwater used by workers, and (3) acute exposure of workers at eastern Carroll Island encountering unexploded ordnance containing white phosphorus or high-explosives during excavation activities. Ingestion of groundwater was the only pathway selected for quantitative evaluation. Potential risks associated with these pathways are discussed below.

8.3.3.2.1 Risk to Workers from Ingestion of Groundwater

EPG Dump Site. Table 8-29 presents the estimated noncarcinogenic hazards associated with ingestion of chemicals in surficial aquifer groundwater at the EPG dump site. No potential carcinogens were selected as chemicals of potential concern in the surficial aquifer at the EPG dump site. The Hazard Index (30) under the RME exposure case exceeds 1 due to thallium.

Bengies Point Road Dump Site. Table 8-30 presents the estimated carcinogenic and noncarcinogenic risks associated with ingestion of chemicals in surficial aquifer and confined aquifer groundwater at the Bengies Point Road dump site. The upper-bound excess lifetime cancer risk for the surficial aquifer is $1x10^{-6}$ under the RME exposure case due to methylene chloride, a B2 carcinogen. Methylene chloride is a common lab contaminant, but there are no blank data available to compare with this concentration to determine whether methylene chloride was introduced in the laboratory or whether it is indicative of site contamination. The Hazard Index (40) for ingestion of surficial aquifer groundwater under the RME exposure case exceeds 1 due to thallium.

No potential carcinogens were selected as chemicals of potential concern in the confined aquifer at the Bengies Point Road dump site. The Hazard Index (0.06) for ingestion of confined aquifer groundwater under the RME exposure case is less than 1 indicating adverse effects are unlikely to occur.

Service Area/Dredge Spoils Site. Table 8-31 presents the estimated carcinogenic and noncarcinogenic risks associated with ingestion of chemicals in surficial aquifer and confined aquifer groundwater at the service area/dredge spoils site. The upper-bound excess lifetime cancer risk for the surficial aquifer is $1x10^{-6}$ under the RME exposure case due to methylene chloride, a B2 carcinogen. As mentioned above, methylene chloride is a common lab contaminant, but there are no

TABLE 8-29

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE CARROLL ISLAND EPG DUMP SITE(a)

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (c)	Target Organ (d)	CDI:RfD Ratio
Surficial Aquifer:					
Manganese (MN)	9.4E-03	1.0E-01	1	CNS	9E-02
Silver (AG)	9.5E-05	3.0E-03	2	Skin (Argyria)	3E-02
Thallium (TL)	2.4E-03	7.0E-05	3,000	Blood/Hair	3E+01
Zinc (ZN)	1.7E-03	2.0E-01	10	Blood (Anemia)	8E-03
HAZARD INDEX	--	--	--	--	> 1 (3E+01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.

(b) USATHAMA chemical codes listed in parentheses.

(c) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(d) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

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TABLE 8-30

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT CARROLL ISLAND BENGIES POINT ROAD DUMP SITE (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Surficial Aquifer:				
Methylene Chloride (CH2CL2)	1.3E-04	7.5E-03	B2	1E-06

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Surficial Aquifer:					
Methylene Chloride (CH2CL2)	4.5E-04	6.0E-02	100	Liver	7E-03
Barium (BA)	2.6E-03	7.0E-02	3	Cardiovasc. Sys.	4E-02
Manganese (MN)	1.8E-02	1.0E-01	1	CNS	2E-01
Silver (AG)	2.4E-04	3.0E-03	2	Skin (Argyria)	8E-02
Thallium (TL)	2.4E-03	7.0E-05	3,000	Blood/Hair	3E+01
HAZARD INDEX	--	--	--	--	> 1 (4E+01)
Confined Aquifer:					
Manganese (MN)	6.5E-03	1.0E-01	1	CNS	< 1 (6E-02)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.

(b) USATHAMA chemical codes listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects: [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

TABLE 8-31

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE CARROLL ISLAND SERVICE AREA/DREDGE SPOILS SITE (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Surficial Aquifer:				
Methylene Chloride (CH2CL2)	1.3E-04	7.5E-03	B2	1E-06

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Surficial Aquifer:					
Methylene Chloride (CH2CL2)	4.5E-04	6.0E-02	100	Liver	7E-03
Barium (BA)	1.4E-03	7.0E-02	3	Cardiovasc. Sys.	2E-02
Manganese (MN)	2.4E-02	1.0E-01	1	CNS	2E-01
Silver (AG)	1.1E-04	3.0E-03	2	Skin (Argyria)	4E-02
Thallium (TL)	2.2E-03	7.0E-05	3,000	Blood/Hair	3E+01
HAZARD INDEX	--	--	--	--	> 1 (3E+01)
Confined Aquifer:					
Manganese (MN)	1.9E-03	1.0E-01	1	CNS	< 1 (2E-02)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.

(b) USATHAMA chemical codes listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects: [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

blank data available with which to compare. The Hazard Index (30) for ingestion of surficial aquifer groundwater at the service area/dredge spoils site exceeds 1 due to thallium.

No carcinogens were selected as chemicals of potential concern in the confined aquifer at the service area/dredge spoils site. The Hazard Index (0.02) for ingestion of confined aquifer groundwater at the service area/dredge spoils site is less than 1 indicating adverse effects are unlikely to occur.

Eastern Carroll Island. Table 8-32 presents the estimated carcinogenic and noncarcinogenic risks associated with ingestion of chemicals in surficial aquifer and confined aquifer groundwater at eastern Carroll Island. The upper-bound excess lifetime cancer risk for the surficial aquifer at eastern Carroll Island is 7×10^{-8} under the RME exposure case due to 1,2-dichloroethane. The Hazard Index (8) for ingestion of surficial aquifer groundwater under the RME exposure case exceeds 1 due to thallium.

No potential carcinogens were selected as chemicals of potential concern in the confined aquifer at eastern Carroll Island. The Hazard Index (0.1) for ingestion of confined aquifer groundwater under the RME exposure case is less than 1.

8.3.3.2.2 Risk to Workers from Inhalation and Dermal Exposures to Chemicals Volatilizating from Groundwater at Carroll Island

Future workers using groundwater from Carroll Island also could be exposed via inhalation of chemicals that volatilize from groundwater during use and via dermal absorption of organic chemicals present in groundwater (inorganic chemicals are not dermally absorbed to any appreciable extent). Such exposures could be associated with use of groundwater from the surficial aquifers at the Bengies Point Road dump site, the service area/dredge spoils site, and eastern Carroll Island. Exposure via these pathways would add to overall exposure and risk. The scientific literature on this subject indicates that the risk associated with these sources may be similar in magnitude to that associated with exposures via ingestion. However, because future workers are not likely to engage in activities that could result in significant inhalation or dermal exposures (e.g., showering or bathing), risks associated with these additional exposure pathways would probably be minimal relative to ingestion risks.

8.3.3.2.3 Risks Associated with Acute Exposures at Carroll Island

Future workers at eastern Carroll Island could encounter unexploded ordnance containing white phosphorus and high-explosives during excavation or other activities involving disturbance of soil. Information concerning the quantity of unexploded ordnance potentially present at Eastern Carroll Island is not available, but the human health risks from any fire and explosion include burns, dismemberment, and death.

8.4 ECOLOGICAL ASSESSMENT

This section assesses potential ecological impacts associated with the chemicals of potential concern at Carroll Island in the absence of remediation. The methods used to assess ecological impacts follow those outlined in Chapter 4 and roughly parallel those used in the human health risk assessment. Below, potentially exposed populations (receptors) are identified. Then information on

TABLE 8-32

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT EASTERN CARROLL ISLAND (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Surficial Aquifer:				
1,2-Dichloroethane (12DCLE)	8.1E-07	9.1E-02	B2	7E-08

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Surficial Aquifer:					
Acetone (ACET)	7.0E-05	1.0E-01	1,000	Kidney/Liver	7E-04
PAHs [noncarcinogenic] [Total]	1.5E-05	4.0E-03	10,000	Eye	4E-03
Trichlorofluoromethane (CCL3F)	7.5E-06	3.0E-01	1,000	Mortality	3E-05
Barium (BA)	5.8E-04	7.0E-02	3	Cardiovasc. Sys.	8E-03
Manganese (MN)	1.9E-02	1.0E-01	1	CNS	2E-01
Silver (AG)	3.4E-05	3.0E-03	2	Skin (Argyria)	1E-02
Thallium (TL)	5.2E-04	7.0E-05	3,000	Blood/Hair	7E+00
Zinc (ZN)	4.2E-04	2.0E-01	10	Blood (Anemia)	2E-03
HAZARD INDEX	--	--	--	--	> 1 (8E+00)
Confined Aquifer:					
Manganese (MN)	1.4E-02	1.0E-01	1	CNS	< 1 (1E-01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.

(b) USATHAMA chemical codes listed in parentheses.

(c) EPA Weight of Evidence for Carcinogenic Effects: [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.

(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

exposure and toxicity is combined to derive estimates of potential impact in these populations. It is emphasized that this ecological assessment is a predictive assessment. Comprehensive field studies of ecological impacts have not yet been conducted at Carroll Island. A series of ecological surveys were conducted at Carroll Island in the early 1970s. These are summarized in the following section.

This ecological assessment is divided into four principal sections. Section 8.4.1 describes the habitat of Carroll Island and identifies the potential receptor species or species groups selected for evaluation. Section 8.4.2 evaluates and provides estimates of potential exposures for the chemicals and receptors of potential concern. Section 8.4.3 summarizes relevant toxicity information for the chemicals of potential concern. Section 8.4.4 provides quantitative and qualitative estimates of ecological impact.

8.4.1 RECEPTOR CHARACTERIZATION

Carroll Island is located between Saltpeter and Seneca Creeks, which connect on the west side of the island to separate it from the mainland. The Gunpowder River is to the east, and Chesapeake Bay is to the southwest. The island is relatively flat consisting of freshwater and estuarine wetlands and open land with sections of forest throughout the island. Seasonal freshwater ponds occur in shallow depressions and pits across the island. Habitat characteristics of Carroll Island are shown in Figure 8-2. Carroll Island is approximately 855 acres in size. Based on the variety of habitat, Carroll Island is expected to support a variety of species.

In a 1970-1973 study of the mammals of Carroll Island, Pinkham et al. (1976) reported the occurrence of the following species: opossum (*Didelphis marsupialis*), masked shrew (*Sorex cinereus fontinalis*), short-tailed shrew (*Blarina brevicauda*), star-nosed mole (*Condylura cristata*), raccoon (*Procyon lotor*), bat, red fox (*Vulpes fulva*), feral dogs (*Canis familiaris*) (one sighting), feral cats (*Felis domesticus*) (two sightings), gray squirrel (*Sciurus carolinensis pennsylvanicus*), eastern harvest mouse (*Reithrodontomys humulis virginianus*), white-footed mouse (*Peromyscus leucopus noveboracensis*), eastern wood rat (*Neotoma floridana magister*), meadow vole (*Microtus pennsylvanicus*), Norway rat (*Rattus norvegicus*), eastern cottontail (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), and white-tailed deer (*Odocoileus virginianus*).[2] Muskrats were very abundant during the survey, and eastern cottontails were the most frequently observed mammal. Based on seven surveys, deer population estimates for the island ranged from 12-24, with an average of 18.4 (Pinkham et al. 1976). Clement observed deer frequently during a site visit in May, 1990. Pinkham et al. (1976) concluded that there was no evidence of adverse effects in mammals resulting from chemical testing. This was based on comparisons of findings on the east side of the island, where chemical testing occurred, with the west side of the island, which was considered the control sector. However, Pinkham et al. (1976) observed the lowest density of mammals in the southeastern portion of the island and concluded that some unidentified effects of chemical testing may be affecting the mammal populations in this area.

Roelle and Slack (1972 in AEHA 1989) concluded that bird life on Carroll Island is diverse and that there were no apparent effects on the birds resulting from chemical testing. In the wetland areas, herons, shorebirds, and wood ducks (*Aix sponsa*) are expected to occur. During a site visit by Clement in May, 1990, six osprey (*Pandion haliaetus*) were observed and two active osprey nests were noted. In addition, bobwhite quail (*Colinus virginianus*), red-winged blackbirds (*Agelaius phoeniceus*),

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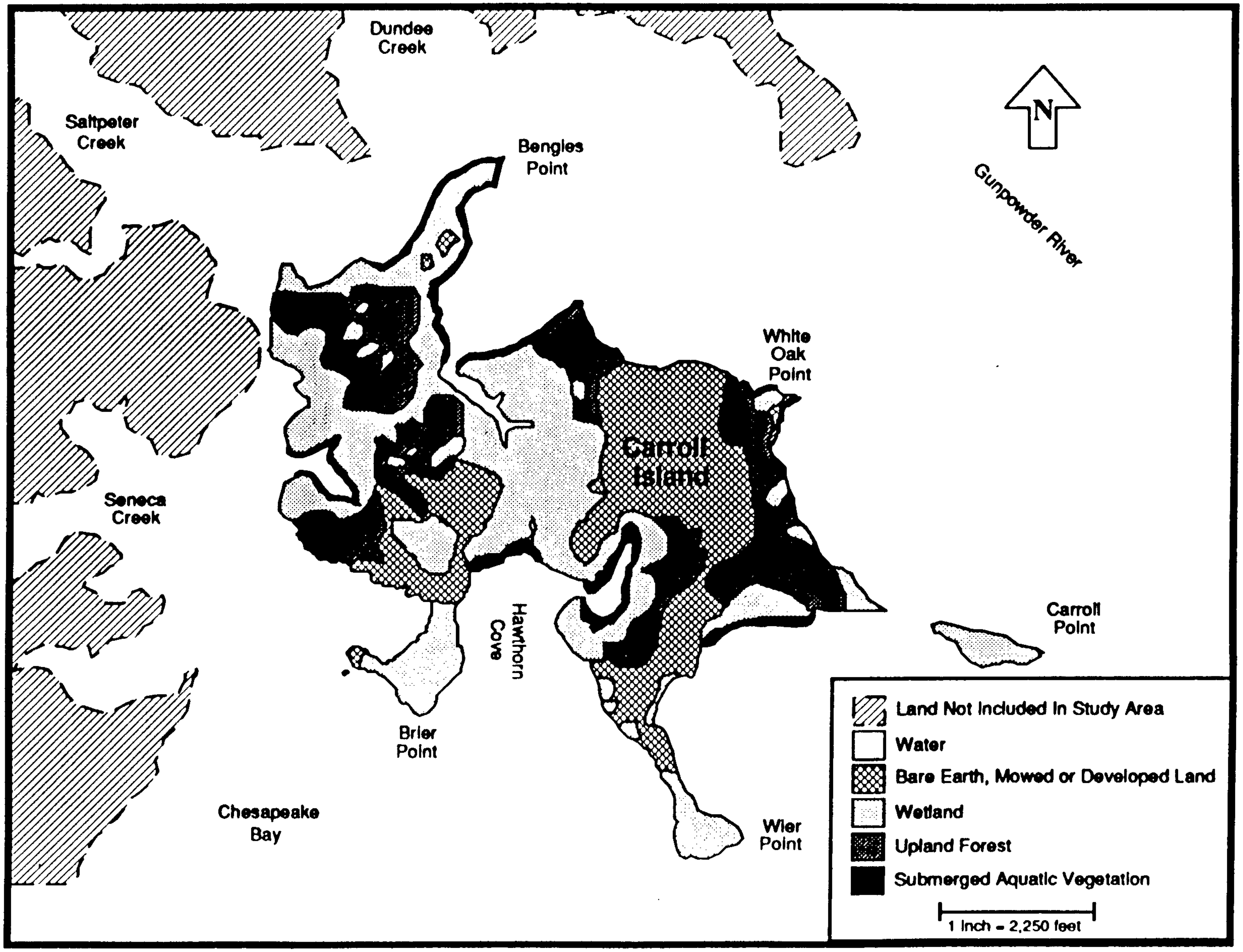
[2] Scientific names are based on those reported in Pinkham et al. (1976).

Figure 8-2

Habitat Characteristics of the Carroll Island Study Area At Aberdeen Proving Ground



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catbirds (*Dumetella carolinensis*), blue jays (*Cyanocitta cristata*), and cardinals (*Cardinalis cardinalis*) were observed.

Amphibians and reptiles are abundant on Carroll Island, and species diversity is high (Slack et al. 1972 in AEHA 1989). In addition, Slack et al. concluded that animal distribution had not been affected by chemical testing. Based on a 1970-1975 study, Ward (1979 in AEHA 1989) indicated that the home range and population structure of spotted turtles was different between the eastern and western portions of the island and that these differences were due to chemical testing on the island.

More than 24 different fish species were collected at two sampling areas (Hawthorne Cove, Carroll Point) in a 1970-1971 study of Carroll Island (Speir 1972). Bay anchovy (*Anchoa mitchilli*), white perch (*Marone americana*), and silversides (Atlantic silversides [*Menidia menidia*], tidewater silversides [*Menidia beryllina*], and rough silversides [*Membras martinica*]) comprised approximately 90% of the total number of fish collected. Alewife (*Alosa pseudoharengus*) comprised approximately 3% of the total catch. No other species comprised more than 2% of the total catch. Fish populations in Hawthorne Cove were nearly twice as abundant as in Carroll Point. This was attributed to more abundant vegetation, higher productivity of sediments, and the sheltered location of Hawthorne Cove. The author concluded that the fish populations around Carroll Island were typical of estuarine communities in the area and that no adverse effects resulting from chemical exposure were evident (Speir 1972).

Aquatic invertebrates on Carroll Island were surveyed by Smrchek (1971). Samples were taken from a large pond on the western part of the island and from sampling stations around the island. Aquatic invertebrates that included protozoans, gastrotrichs, rotifers, moss animals, oligochaetes, leeches, snails, clams, ostracods, fairy shrimps, cladocerans, copepods, shrimps, crabs, amphipods, sow bugs, beetles, flies, and mosquitos were collected. Overall, the study indicated that there was an abundant mixture of aquatic invertebrates associated with Carroll Island, including freshwater and marine species that are tolerant of brackish conditions and several distinct brackish species (Smrchek 1971). The seasonal freshwater ponds located throughout the island probably provide habitat for a variety of these species.

As discussed in Chapter 4, it is not feasible to assess potential impacts in each of the species potentially present at Carroll Island, and for this reason indicator species or species groups were selected for further evaluation. The selection of indicator species for Carroll Island was driven by several factors including the potential for exposure, the sensitivity or susceptibility to chemical exposures, the availability of toxicity data, the availability of chemical data for potential exposure media, ecological significance, and societal value.

The selection of indicator species for this assessment was influenced primarily by the availability of chemical data for potential exposure media. Surface water is the only potential ecological exposure medium for which sampling data are available. Many of the surface water samples collected during the USGS study were from temporary freshwater pools or seasonal ponded areas. Others were collected from existing structures that collect or drain water (e.g., sumps, sluice pipes and water treatment units). These types of surface waters provide habitat primarily for invertebrate species (e.g., insects) and possibly seasonal habitat for amphibians. They do not support fish populations nor are they likely to be used to any significant degree by terrestrial species that inhabit or feed in marshes or more permanent water bodies (e.g., great blue herons and muskrats). Therefore, the principal receptors for this assessment are limited to aquatic invertebrates, amphibians, and the terrestrial species that feed on them. Potential impacts on aquatic and terrestrial wildlife that inhabit or feed in the marshes of Carroll Island or in adjacent Saltpeter Creek and the Chesapeake Bay cannot be evaluated with any degree of confidence, because the few surface water samples collected from these waters are not sufficient to characterize potential ecological impacts in these areas.

Based on these considerations, the receptor species selected for evaluation are as follows:

Aquatic Species

Amphibians:

- Green frog. This species is probably abundant at Carroll Island and may use the small, seasonally ponded areas for breeding.

Invertebrates:

- Aquatic insects/insect larvae. As mentioned above, species within this group probably inhabit the seasonal, freshwater ponds on Carroll Island. They also could occur in the marshes and estuarine shoreline of Carroll Island.

Terrestrial Species

Birds:

- Spotted sandpiper. This species was also selected for evaluation because of its probable common presence at Carroll Island and because it could feed on aquatic insects and other invertebrates living in seasonal ponds, as well as in the marshes and estuarine shoreline of Carroll Island.

The other species listed in Chapter 4 as potential indicator species were not selected for evaluation at Carroll Island primarily because information is lacking on chemical levels in the habitats used by these other species.

Appendix D provides species profiles for the green frog and spotted sandpiper. These profiles should be consulted for information on the ecology of these species. Such profiles are not provided for aquatic invertebrates, due to the large diversity of species comprising this broadly defined receptor group.

8.4.2 POTENTIAL EXPOSURE PATHWAYS AND QUANTIFICATION OF EXPOSURE

In this section, the potential pathways by which the selected indicator species and species groups could be exposed to chemicals of potential concern in surface water at Carroll Island are presented. Exposure was quantified for selected exposure pathways. No pathways exist by which wildlife could be exposed to chemicals of potential concern in groundwater, the only other media for which sampling data are currently available.

Potential exposures are described separately in the following sections for aquatic and terrestrial receptors.

8.4.2.1 Aquatic Life Exposures

As discussed in Chapter 4, aquatic life could be exposed to chemicals in surface water by several pathways. However, most available aquatic toxicity data express toxicity as a function of the concentration in the exposure medium (i.e., surface water concentration). Thus, in this assessment, exposures to aquatic life were based on concentrations in surface water. Measured concentrations of chemicals of potential concern in surface water were used to assess potential aquatic life exposures. The exposure concentration is the lower value of the 95% upper confidence limit on the arithmetic mean or the maximum detected concentrations. Concentrations for the evaluation of aquatic life exposures are presented in Table 8-33.

8.4.2.2 Terrestrial Wildlife Exposures

As discussed in Chapter 4, terrestrial wildlife could be exposed to chemicals in surface water by a variety of pathways. However, adequate data are not available to assess wildlife exposures via all pathways; therefore, only exposures via ingestion of surface water and food were selected for consideration in the ecological assessments for the various APG study areas. For this assessment, only ingestion of contaminated food was evaluated. Ingestion of surface water was not selected for evaluation because exposures and impacts via this pathway are likely to be much less than from ingestion of food that has accumulated chemicals from the surrounding medium.

Spotted sandpipers are the only terrestrial species for which exposures were evaluated. Spotted sandpipers are likely to feed in the marshes and shoreline areas of Carroll Island and could feed in the seasonal ponded areas on the upland portions of the island. The spotted sandpiper is an aquatic insectivore and feeds predominantly on sediment-dwelling invertebrates. Insects are the principal component of the diet, although marine worms, small crustaceans, and small mollusks also may be eaten. This assessment evaluates sandpiper exposure via ingestion of aquatic invertebrates that have accumulated chemicals from surface water at Carroll Island.

Chemical concentrations in the sandpiper diet at Carroll Island are estimated in this assessment using bioconcentration factors (BCFs) and chemical concentrations in surface water. BCFs provide a measure of the extent of chemical partitioning at equilibrium between a biological medium such as invertebrates and an external medium such as water. For most chemicals and most situations, water is considered to be the predominant source of chemical residues in aquatic organisms (Neff 1979).[3] Use of BCFs to estimate chemical concentrations in aquatic invertebrates at Carroll Island is therefore a reasonable approach in the absence of measured tissue concentrations.

Information on the bioconcentration potential of the chemicals of potential concern in surface water was obtained from the available literature. A summary of bioconcentration data for the chemicals of potential concern is presented in the chemical-specific ecological toxicity profiles in Appendix C. In selecting BCFs for use in this risk assessment the following screening procedures were used:

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[3] The principal exceptions to this are highly hydrophobic organic compounds such as PCBs, dioxins, and DDT.

TABLE 8-33

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AT CARROLL ISLAND

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
EPG DUMP SITE				
Inorganic Chemicals:				
Aluminum (AL)	NA	NA	531	531
Sulfate (S04)	NA	NA	113,000	113,000
BENGIES POINT ROAD DUMP SITE				
Inorganic Chemicals:				
Aluminum (AL)	840	2,000,000	2,320	2,320
Antimony (SB)	54	1,500	147	147
Beryllium (BE)	3.6	7.2	5.9	5.9
Cadmium (CD)	4.3	89	11.2	11.2
Copper (CU)	22	110	37.7	37.7
Iron (FE)	6,500	150,000,000	16,400	16,400
Manganese (MN)	440	400,000	1,210	1,210
Nickel (NI)	32	140	66.3	66.3
Silver (AG)	3.1	6.9	5.5	5.5
Sulfate (S04)	23,000	37,000,000	76,900	76,900
SERVICE AREA				
Inorganic Chemicals:				
Copper (CU)	7.3	NA	10.5	10.5
Iron (FE)	3,400	NA	6,550	6,550
Sulfate (S04)	18,000	NA	30,400	30,400
Thallium (TL)	80	NA	113	113
EASTERN CARROLL ISLAND				
Organic Chemicals:				
Benzene (C6H6)	0.3	0.4	0.6	0.4
1,1,2,2-Tetrachloroethane (TCLEA)	0.4	0.7	1.2	0.7
Toluene (MEC6H5)	0.3	0.6	0.9	0.6
Inorganic Chemicals:				
Aluminum (AL)	280	1,100	637	637
Antimony (SB)	32	53	89.6	53
Cadmium (CD)	2.6	3.8	6.2	3.8
Copper (CU)	22	37	35.7	35.7
Iron (FE)	2,800	22,000	4,520	4,520
Sulfate (S04)	12,000	30,000	32,600	30,000
Zinc (ZN)	140	4,000	800	800

See footnotes on the following page.

TABLE 8-33 (Continued)

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AT CARROLL ISLAND

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
CHESAPEAKE BAY NEAR LOWER ISLAND DISPOSAL SITE				
Organic Chemicals:				
Thiodyglycol (TDGCL)	140	NA	138	138
Inorganic Chemicals:				
Aluminum (AL)	1,200	NA	1,735	1,735
Copper (CU)	20	NA	24.2	24.2
Iron (FE)	3,900	NA	5,450	5,450
Silver (AG)	4.0	NA	5.6	5.6
Sulfate (S04)	53,000	NA	94,900	94,900
CHESAPEAKE BAY NEAR THE WIND TUNNEL				
Inorganic Chemicals:				
Aluminum (AL)	NA	NA	676	676
Sulfate (S04)	NA	NA	73,900	73,900
SALTPETER CREEK				
Inorganic Chemicals:				
Aluminum (AL)	570	1,100	866	866
Sulfate (S04)	100,000	110,000	108,000	108,000

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

NA = Not applicable; single sample.

- Data from laboratory studies were used in preference to field data because laboratory studies involve considerably greater control of the parameters affecting bioaccumulation (e.g., chemical concentration, exposure duration).
- The highest BCF reported in the literature for insects was selected for use in this assessment. If data on insects were not available, the highest BCF for small crustaceans or marine worms was used.

Sandpiper exposures to chemicals in food are evaluated only for chemicals with BCFs greater than 300. As discussed in Chapter 4, BCFs greater than 300 generally are considered to result in significant bioaccumulation in aquatic life (EPA 1989c). As a result, sandpiper exposures are not evaluated for any volatile chemical or for thiodiglycol because these chemicals do not bioaccumulate appreciably in aquatic life. BCFs for cadmium, manganese, nickel, and zinc are presented in Table 8-34. No other chemicals of potential concern are expected to accumulate appreciably in the sandpiper diet.

Once BCFs were selected, chemical concentrations in food were estimated using the selected BCF and the measured surface water concentrations in an equilibrium-partitioning model:

$$C_f = C_w * BCF \qquad \text{(Eq. 2)}$$

where:

C_f = chemical concentration in food (mg/kg);

C_w = chemical concentration in the water column (mg/L); and

$BCF_{f:w}$ = food:water BCF (mg/kg food per mg/L water).

For chemical concentrations in water, the total chemical concentration was used because information on dissolved concentrations is not available. This resulted in overestimates of exposure because chemicals sorbed onto particles are not available for uptake. The RME concentrations reported in Table 8-33 were used to estimate concentrations in the sandpiper diet. The estimated concentrations in the sandpiper diet are presented in Table 8-35.

Sandpiper exposures were estimated using the following equation:

$$Dose = C_f * FI_f / BW \qquad \text{(Eq. 3)}$$

where:

Dose = exposure (mg/kg);

C_f = concentration in food (mg chemical/kg food);

FI_f = daily food intake by sandpipers of contaminated aquatic life (kg); and

BW = body weight (kg).

TABLE 8-34

INVERTEBRATE BIOCONCENTRATION FACTORS (BCFs) FOR EVALUATION OF SANDPIPER EXPOSURES TO CHEMICALS IN SURFACE WATER AT CARROLL ISLAND

Chemical (a)	BCF	Basis	Reference
Cadmium	4,190	28-day, bioconcentration in the caddisfly (Hydropsyche betteni)	Spehar et al. (1978) in EPA (1985a)
Manganese	3,900	Chironomid larvae	Salanki et al. (1982) in AQUIRE (1990)
Nickel	473 (b)	84-days blue mussel (Mytilus edulis) edible tissues	Zarooglan and Johnson (1984) in EPA (1986b)
Zinc	1,130	14-day, bioconcentration in mayfly (Ephemerella grandis)	Nehring (1976) in EPA (1987)

(a) Only chemicals of potential concern with measured BCFs greater than 300 are listed here. See text for rationale.
(b) BCF for mollusk used in absence of information on insects.

TABLE 8-35

ESTIMATED EXPOSURES IN SANDPIPERS INGESTING INVERTEBRATES THAT HAVE ACCUMULATED CHEMICALS FROM SURFACE WATER AT CARROLL ISLAND

Chemical	RME Surface Water Concentration (mg/L) (a)	BCF (mg/kg insect per mg/L water) (b)	Estimated Concentration in Insects (mg/kg insect)	Estimated Dose (mg/kg bw) (c)
Bengies Point Road Dump Site				
Cadmium	0.0112	4,190	47	4.1
Manganese	1.21	3,900	4,700	420
Nickel	0.0663	473	31	2.8
Eastern Carroll Island				
Cadmium	0.0038	4,190	16	1.4
Zinc	0.8	1,130	900	80

(a) Reported previously in Table 8-33.
(b) Reported previously in Table 8-34.
(c) Calculated assuming a sandpiper weighs 43 g (0.043 kg) and ingests 3.8 g (0.0038 kg) of insects from Carroll Island surface water each day.

For this assessment, sandpipers were assumed to weigh 43 g (0.043 kg) and ingest 7.5 g (0.0075 kg) of food each day, all of which was assumed to be insects or other invertebrates (see Appendix D for source of values). Sandpipers were further assumed to obtain 50% of their daily insect intake, or 3.8 g (0.0038 kg), from any one source area at Carroll Island. The resulting estimates of exposure are presented in Table 8-35. Exposures were estimated for the Bengies Point Road dump site and eastern Carroll Island, as only these areas contain chemicals that could accumulate appreciably in aquatic life.

8.4.3 TOXICITY ASSESSMENT

The general methodology for the development of toxicity values for the evaluation of ecological impacts has been described in Chapter 4. The toxicity values used to evaluate aquatic life and terrestrial wildlife impacts are presented in this section along with a brief description of the basis of each value. Tables 8-36 and 8-37 present acute and chronic toxicity values for the assessment of aquatic life impacts (including aquatic amphibian larvae) from exposure to chemicals of potential concern in surface water. In these tables, two values are presented for chemicals of potential concern in both fresh and estuarine waters. The freshwater values were used to assess impacts to aquatic life at the Bengies Point Road dump site and the service area, and the lower of freshwater and saltwater values were used to assess impacts to aquatic life at the five other areas. Table 8-41 presents toxicity values for the assessment of impacts in sandpipers. Appendix C presents complete ecological toxicity summaries for all chemicals of potential concern for which exposures were evaluated.

8.4.4 ESTIMATES OF IMPACTS

Impacts on aquatic and terrestrial wildlife exposed to chemicals of potential concern at Carroll Island were evaluated by comparing estimated exposures with the appropriate toxicity value for the chemical and receptors of concern. Exposures that exceed the selected toxicity value suggest that impacts may be possible in the species evaluated or in similar species. Potential impacts in aquatic life are discussed below in Section 8.4.4.1, and potential impacts in sandpipers are discussed in Section 8.4.4.2.

8.4.4.1 Potential Impacts on Aquatic Life

Aquatic life exposures to chemicals in surface waters at Carroll Island were evaluated. Potential impacts for each area are discussed below and summarized in Table 8-39.

EPG Dump Site. Chronic toxicity values for aluminum and sulfate are exceeded at this area. Thus, there is the potential for some aquatic receptors to experience adverse effects from long-term exposure to these chemicals. Acute effects are not expected because the acute toxicity values are not exceeded.

Bengies Point Road Dump Site. Acute toxicity values are exceeded for aluminum, antimony, cadmium, copper, iron, and silver. Thus, acute effects could occur in some aquatic receptors at this area. Chronic effects could also occur because chronic toxicity values are exceeded for all of the chemicals of potential concern except nickel. It should be noted that antimony, beryllium, cadmium, silver, and sulfate were detected only once in the four samples collected. Thus, their potential impacts may not be as significant as copper, iron, and manganese, which were detected in all four of the

Table 8-36

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT CARROLL ISLAND

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Benzene (C6H6)	1,630	24-hour LC50 in brine shrimp	Abernethy et al. (1986) in AQUIRE (1990)
1,1,2,2-Tetrachloroethane (TCLEA)	930	48-hour LC50 in Daphnia; factor of 10 applied to account for interspecies variation	LeBlanc (1980)
Thiodiglycol (TDGCL)	684,000	96-hour LC50 in sheepshead minnow estimated based on SAR	See Appendix C for derivation
Toluene (MEC6H5)	641	24-hour LC50 in brine shrimp	Abernethy et al. (1986) in AQUIRE (1990)
Inorganic Chemicals:			
Aluminum (AL)	750	AWQC (freshwater)	EPA (1988a)
Antimony (SB)	88	Proposed AWQC (freshwater)	EPA (1988b)
Beryllium (BE)	130	Insufficient data to develop criterion; value is acute LOEC	EPA (1986c)
Cadmium (CD)	1.8 (d)	AWQC (freshwater)	EPA (1985a)
Copper (CU)	2.9	AWQC (saltwater)	EPA (1985b)
	9.2 (d)	AWQC (freshwater)	EPA (1985b)
Iron (FE)	320	96-hour LC50 in aquatic insects	Warnick and Bell (1969) in EPA (1976)
Manganese (MN)	1,450	96-hour LC50 in rainbow trout	Davies (1980)
Nickel (NI)	75	AWQC (saltwater)	EPA (1986b)
	790 (d)	AWQC (freshwater)	EPA (1986b)
Silver	0.92	Proposed AWQC (freshwater)	EPA (1990)
Sulfate (SO4)	190,000	LC50 in diatoms; factor of 10 applied to account for interspecies variation	Patrick et al. (1968)
Thallium	1,400	Insufficient data to develop criterion; value is acute LOEC	EPA (1986c)
Zinc (ZN)	65 (d)	AWQC (freshwater)	EPA (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Hardness dependent criterion (hardness of 50 mg/L as CaCO3 used as lower limit).

AWQC = Ambient Water Quality Criterion.
LOEC = Lowest-observed-effect concentration.
SAR = Structure activity relationships.

TABLE 8-37

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT CARROLL ISLAND

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
Benzene (C6H6)	8,640	LC50 in ELS test with rainbow trout	Black et al. (1982) in AQUIRE (1990)
1,1,2,2-Tetrachloroethane (TCLEA)	690	28-day LOEC based on reproductive effects in Daphnia; factor of 10 applied to account for interspecies variation	Richter et al. (1983) in AQUIRE (1990)
Thiodiglycol (TDGCL)	1,060,000	14-day LC50 in fish estimated based on SAR; factor of 10 applied to account for interspecies variation	See Appendix C for derivation
Toluene (MEC6H5)	25	LC50 in ELS tests with rainbow trout	Black et al. (1982) in AQUIRE (1990)
Inorganic Chemicals:			
Aluminum	87	AWQC (freshwater)	EPA (1988a)
Antimony (SB)	30	Proposed AWQC (freshwater)	EPA (1988b)
Beryllium	5.3	Insufficient data to develop criterion; value is LOEC (freshwater)	EPA (1986c)
Cadmium (CD)	0.7 (d)	AWQC (freshwater)	EPA (1985a)
Copper (CU)	2.9	AWQC (saltwater)	EPA (1985b)
	6.5 (d)	AWQC (freshwater)	EPA (1985b)
Iron (FE)	1,000	AWQC (freshwater)	EPA (1986c)
Manganese (MN)	10	Growth reduction in Pacific oyster larvae exposed for 14-days	Watling (1983) in AQUIRE (1990)
Nickel	8.3	AWQC (saltwater)	EPA (1986b)
	88 (d)	AWQC (freshwater)	EPA (1986b)
Silver	0.12	Proposed AWQC (freshwater)	EPA (1990)
Sulfate (SO4)	76,000	Estimated chronic value; extrapolated from an LC50 for diatoms by applying an ACR of 25	Patrick et al. (1968)
Thallium	40	Insufficient data to develop criterion; value is LOEC (freshwater)	EPA (1986c)
Zinc (ZN)	58.9 (d)	AWQC (freshwater)	EPA (1987)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Hardness dependent criterion (hardness of 50 mg/L as CaCO3 used as lower limit).

ACR = Acute to chronic ratio.
AWQC = Ambient Water Quality Criterion.
ELS = Early lifestage.
LOEC = Lowest-observed-effect concentration.
SAR = Structure activity relationships.

TABLE 8-38

TOXICITY VALUES FOR ASSESSMENT OF SANDPOPER DIETARY EXPOSURES TO CHEMICALS AT CARROLL ISLAND

		Basis for Value (c)					
Chemical (a)	Toxicity Value (mg/kg bw) (b)	Test Species	Exposure Duration	Dose (mg/kg bw)	Effect	Source	Uncertainty Factor
Cadmium (CD)	0.13	Poultry	Not reported	12.5 (d)	Reduced egg fertility and hatchability	Puls (1988)	100 (to account for interspecies differences and to extrapolate a NOAEL from an effect level)
Manganese (MN)	51	Turkey	21 Days	510 (d)	NOAEL; decreased growth	Vohra and Kratzer (1968) in NAS (1980)	10 (to account for interspecies variation)
Nickel (NI)	3.75	Chicken	4 Weeks	37.5 (d)	NOAEL; decreased growth	NAS (1980)	10 (to account for interspecies variation)
Zinc (ZN)	7.8	Japanese quail	2 Weeks	7.8 (d)	NOAEL	NAS (1980)	None (NOAEL based on data for 3 or more species)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using methodology outlined in Chapter 4.
(c) See Appendix C for additional information on the referenced studies.
(d) Estimated dosage. Dietary chemical concentrations reported in the study have been converted to dosages using the dietary conversion factors reported in Lehman (1954). See Appendix C for more detail.

TABLE 8-39

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN SURFACE WATER AT CARROLL ISLAND

(Concentrations reported in ug/L)

Study Area/ Chemical (a)	Toxicity Value (b)		Exposure Concentration (c)	Toxicity Value Exceeded
	Acute	Chronic		
EPG Dump Site				
Inorganic Chemicals:				
Aluminum (AL)	750	87	531	Chronic
Sulfate (SO4)	190,000	76,000	113,000	Chronic
Bengies Point Road				
Inorganic Chemicals:				
Aluminum (AL)	750	87	2,320	Acute, Chronic
Antimony (SB)	88	30	147	Acute, Chronic
Beryllium (BE)	130	5.3	5.9	Chronic
Cadmium (CD)	1.8	0.7	11.2	Acute, Chronic
Copper (CU)	9.2	6.5	37.7	Acute, Chronic
Iron (FE)	320	1,000	16,400	Acute, Chronic
Manganese (MN)	1,450	10	1,210	Chronic
Nickel (NI)	790	88.0	66.3	--
Silver (AG)	0.92	0.12	5.5	Acute, Chronic
Sulfate (SO4)	190,000	76,000	76,900	Chronic
Service Area				
Inorganic Chemicals:				
Copper (CU)	9.2	65.0	10.5	Acute, Chronic
Iron (FE)	320	1,000	6,550	Acute, Chronic
Sulfate (SO4)	190,000	76,000	30,400	--
Thallium (TL)	1,400	40	113	Chronic
Eastern Carroll Island				
Organic Chemicals:				
Benzene (C6H6)	1,630	8,640	0.4	--
1,1,2,2-Tetrachloroethane (TCLEA)	930	690	0.7	--
Toluene (MEC6H5)	641	25	0.6	--
Inorganic Chemicals:				
Aluminum (AL)	750	87	637	Chronic
Antimony (SB)	88	30	53	Chronic
Cadmium (CD)	1.8	0.7	3.8	Acute, Chronic
Copper (CU)	2.9	2.9	35.7	Acute, Chronic
Iron (FE)	320	1,000	4,520	Acute, Chronic
Sulfate (SO4)	190,000	76,000	30,000	--
Zinc (ZN)	65	58.9	800	Acute, Chronic
Chesapeake Bay Near Lower Island				
Organic Chemicals:				
Thiodiglycol (TDGCL)	684,000	1,060,000	138	--
Inorganic Chemicals:				
Aluminum (AL)	750	87	1,735	Acute, Chronic
Copper (CU)	2.9	2.9	24.2	Acute, Chronic
Iron (FE)	320	1,000	5,450	Acute, Chronic
Silver (AG)	0.92	0.12	5.6	Acute, Chronic
Sulfate (SO4)	190,000	76,000	94,900	Chronic

See footnotes on the following page.

TABLE 8-39 (Continued)

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH EXPOSURE CONCENTRATIONS IN SURFACE WATER AT CARROLL ISLAND

(Concentrations reported in ug/L)

Study Area/ Chemical (a)	Toxicity Value (b)		Exposure Concentration (c)	Toxicity Value Exceeded
	Acute	Chronic		
Chesapeake Bay Near Wind Tunnel				
Inorganic Chemicals:				
Aluminum (AL)	750	87	676	Chronic
Sulfate (SO4)	190,000	76,000	73,900	--
Saltpeter Creek				
Inorganic Chemicals:				
Aluminum (AL)	750	87	866	Acute, Chronic
Sulfate (SO4)	190,000	76,000	108,000	Chronic

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Tables 8-36 and 8-37. Freshwater values used for Bengies Point and Service Area sites; the lower of either fresh or saltwater values are used for other sites. See text for further discussion.
(c) Reported previously in Table 8-33.

-- No toxicity value exceeded.

samples. The RME concentration of cadmium also exceeds the acute and chronic criteria based on the maximum estimated hardness value of approximately 200 mg/L.

Service Area. Acute and chronic toxicity values are exceeded for copper and iron. The chronic value is also exceeded for thallium. The exposure concentration for sulfate does not exceed the available toxicity values for this chemical.

Eastern Carroll Island. Exposure concentrations for the organic chemicals of concern are well below the toxicity values used in this assessment. Additive toxicity from exposure to these chemicals is not expected since the exposure concentrations are so much less than the individual toxicity values. Acute toxicity values are exceeded for cadmium, copper, iron, and zinc. Chronic values are exceeded for these chemicals, as well as for aluminum and antimony. Toxicity values are not exceeded for sulfate. It should be noted that potential impacts across eastern Carroll Island may be greatest from copper and iron since these chemicals were detected in all seven of the samples collected. Antimony and cadmium probably contribute less to the total risks to aquatic receptors, given that they were detected only once out of the seven samples.

Chesapeake Bay Near the Lower Island Disposal Site. The exposure concentration for thiodiglycol is well below the available toxicity values, thus no adverse effects are expected from exposure to this chemical. The acute and chronic toxicity values are exceeded by the exposure concentrations for aluminum, copper, iron, and silver. The chronic toxicity value for sulfate also is exceeded.

Chesapeake Bay Near the Wind Tunnel. The chronic toxicity value for aluminum is exceeded at this area. No other toxicity values are exceeded. Thus, some aquatic receptors may be at risk of adverse effects from long-term exposures to aluminum.

Saltpeter Creek. At this area, the acute and chronic toxicity values for aluminum are exceeded. The chronic value is exceeded by approximately 10 times. The exposure concentration for sulfate is also greater than the chronic toxicity value. Aluminum and sulfate were detected above background in all four samples collected from Saltpeter Creek.

8.4.4.2 Potential Impacts on Sandpipers

Dietary exposures were evaluated for sandpipers feeding in surface waters at the Bengies Point Road dump site and eastern Carroll Island. Table 8-40 presents a comparison of selected toxicity values with estimated exposures in sandpipers. The results of these comparisons are as follows:

- Bengies Point Road Dump Site. Sandpipers may be at risk of adverse effects from exposure to cadmium and manganese. The estimated dose of cadmium exceeds the sandpiper toxicity value by more than 30 times, and for manganese exceeds the toxicity value by an approximate factor of 8. The estimated dose of nickel is less than the toxicity value for sandpipers, and therefore this chemical is not expected to result in adverse effects.

- Eastern Carroll Island. Sandpipers may be at risk of adverse effects from exposure to cadmium and zinc in their diet. The estimated dose of cadmium is approximately 11 times greater than the toxicity value, and the zinc dose is about 10 times greater than the zinc toxicity value for birds.

TABLE 8-40

COMPARISON OF TOXICITY VALUES WITH ESTIMATED DOSAGES FOR SANDPIPERS EXPOSED TO CHEMICALS THAT HAVE ACCUMULATED IN FOOD AT CARROLL ISLAND

Study Area/ Chemical (a)	Toxicity Value (b) (mg/kg bw)	Estimated Dosage (c) (mg/kg bw)	Toxicity Value Exceeded?
Bengies Point Road			
Cadmium (CD)	0.13	4.1	Yes
Manganese (MN)	51	420	Yes
Nickel (NI)	3.75	2.8	No
Eastern Carroll Island			
Cadmium (CD)	0.13	1.4	Yes
Zinc (ZN)	7.8	80	Yes

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Table 8-38.
(c) Reported previously in Table 8-35.

These comparisons suggest that sandpipers and other similar shorebirds feeding in the surface waters near the Bengies Point Road dump site or in eastern Carroll Island could be impacted by elevated dietary levels of cadmium, manganese, and zinc. Cadmium toxicity in birds has been associated with reduced egg fertility and hatchability. Excess dietary manganese and zinc have been associated with decreased growth in birds. Toxic effects of this type could result in alterations in population number and structure in sandpipers living on Carroll Island. Given the size of the eastern Carroll Island study area, it potentially could support a large number of spotted sandpipers, as this species has a relatively small home range. Thus, toxic dietary levels of metals across this area could impact a significant number of sandpipers, resulting in local population impacts. Furthermore, impacts on the population of sandpipers using Carroll Island could contribute to cumulative impacts associated with APG as a whole.

8.5 UNCERTAINTIES

As in any risk assessment, there is a large degree of uncertainty associated with the estimates of human health and ecological risks for Carroll Island. Consequently, these estimates should not be regarded as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the predicted risks and to placing the predicted risks in proper perspective. The principal sources of uncertainty associated with the APG risk assessments were discussed in general in Chapter 4. Some of the key sources of uncertainty associated with the estimates of risk for Carroll Island are summarized below.

8.5.1 UNCERTAINTIES RELATED TO SELECTION OF CHEMICALS FOR EVALUATION

Because no site-specific or regional background data were available for groundwater, the site-relatedness of inorganic chemicals in groundwater was determined by comparing on-site chemical concentrations with national background data. As a result, inorganic chemicals that may not be site-related were selected for evaluation, even though historical information provides no indication that they were associated with past activities at Carroll Island. This is particularly critical at Carroll Island, because thallium is driving the estimates of noncarcinogenic risk for ingestion of surficial aquifer groundwater by future workers at Carroll Island. Consequently, including chemicals in this risk assessment that are present at natural levels may have resulted in overestimates of impact associated with Carroll Island.

Because no site-specific background data were available for surface water at Carroll Island, the site-relatedness of inorganic chemicals in surface water was determined by comparing on-site concentrations with background data collected from areas near APG. The degree to which these background data are representative of freshwater and estuarine wetlands at Carroll Island or of Seneca Creek, Saltpeter Creek, Gunpowder River, and the Chesapeake Bay is probably limited. As a result, inorganic chemicals that may not be site-related were selected for evaluation, even though historical information provides no indication that they were associated with past activities at Carroll Island. This is particularly critical at Carroll Island because inorganic chemicals are driving the estimates of impact for aquatic and terrestrial wildlife. Consequently, including chemicals in this risk assessment that are present at natural levels may have resulted in overestimates of impact associated with Carroll Island.

No blank data were available for the groundwater and surface water data. Therefore, the site-relatedness of common laboratory contaminants such as methylene chloride is unknown. Including possible laboratory contaminants in the evaluations of risks may result in overestimate of risk. This is particularly important for the evaluation of drinking water exposures in this assessment, given that the carcingenic risks associated with ingestion of groundwater from the surficial aquifers at the Bengies Point Road dump site and the service area/dredge spoils site were due to methylene chloride.

There is also uncertainty regarding the nature and extent of contamination in groundwater, surface water, soil, and sediment at Carroll Island. Groundwater and surface water analysis did not include the chemicals of potential concern listed in Table 8-17. Surface soil and sediment samples were collected, but results are not available to evaluate potential exposures and risks. Subsurface soil samples have not been collected.

8.5.2 UNCERTAINTIES ASSOCIATED WITH THE MODELS AND ASSUMPTIONS USED TO ESTIMATE EXPOSURES

The lack of surface water sampling data from principal habitat areas at Carroll Island (i.e., on-site marshes, Saltpeter Creek, and the Chesapeake Bay) greatly affects the certainty of the evaluation of ecological impacts. Given the available data, the evaluations of ecological impacts associated with Carroll Island are very incomplete.

There also is some uncertainty associated with the estimates of bioconcentration in aquatic life. These estimates were based on a simple partitioning model that assumed equilibrium conditions between the aquatic organism and surface water. The approach also assumed that bioaccumulation in species living at Carroll Island was similar to that reported in the literature for other species. The extent that this assumption is true affects the accuracy of the exposure estimates. Also, total surface water concentrations were used in the model, because dissolved concentrations were not available. This resulted in overestimates of bioaccumulation, because chemicals that are sorbed onto particles are not available for uptake.

A large degree of uncertainty is associated with the assumption that groundwater at Carroll Island will be used in the future and that chemical concentrations in groundwater will remain constant.

8.5.3 UNCERTAINTIES IN THE TOXICITY ASSESSMENT

Uncertainties in the human health toxicity assessment also contribute to overall uncertainties associated with estimates of risk. An uncertainty factor of 3,000 was used to derive the RfD for thallium, resulting in a relatively low oral toxicity value. Because thallium drives the estimates of noncarcinogenic risk for ingestion of surficial aquifer groundwater by future workers at Carroll Island, uncertainties associated with the toxicity value for this chemical have particular relevance in this risk assessment.

There is uncertainty in the values used to estimate ecological toxicity. Conservative assumptions were made to avoid underestimating toxicity. For example, in cases where both freshwater and saltwater toxicity values are available, the lower value was used. For hardness-dependent AWQC (for example, cadmium and zinc) a lower hardness limit of 50 mg/L was used, even though estimated hardness values were less than 50 mg/L in some cases, because EPA stated that it is not advisable to extrapolate below 50 mg/L because of limitations of the toxicity data.[4] There is also uncertainty in estimating chronic toxicity values from acute values using an acute-to-chronic ratio (for example, sulfate) and from estimating toxicity values from structure-activity relationships (for example, thiodiglycol).

8.6 PRINCIPAL DATA NEEDS

Investigations to date have not provided a complete and exhaustive characterization of the type and degree of contamination at Carroll Island. As a result, additional investigation is needed to assess more definitively existing or potential impacts. The principal types of additional data needed are data on the nature and extent of contamination. Specific data needs are summarized below.

Data on the Nature and Extent of Contamination

- Surface soil and sediment sampling data are needed to permit an evaluation of potential impacts in occassional human users of Carroll Island and in ecological receptors.
- Subsurface soil samples should be collected to provide information concerning the burial depths of waste materials, the thickness of soil covers at the disposal sites, and the contents of the disposal sites. Subsurface soil samples would also provide information on the extent of contamination in the testing areas.
- Additional surface water and sediment samples should be collected from the marsh areas in eastern Carroll Island and from Hawthorne Cove, the Chesapeake Bay, and Saltpeter Creek adjacent to Carroll Island so that the potential impacts on aquatic and terrestrial wildlife in these areas can be evaluated more completely.
- For each media sampled, background samples should be collected for analysis to permit a more accurate assessment of the site-relatedness of inorganic chemicals. Background groundwater and soil samples should be collected from the mainland west of the site. Background soil samples collected from the mainland should be of the same soil type. Background surface water and sediment samples should be collected from similar systems as those at Carroll Island. A sufficient number of samples should be collected to permit statistical evaluation.
- Samples from all media should be analyzed for the full range of chemicals potentially present at Carroll Island.
- Once contamination at Carroll Island has been better defined, additional recommendations can be made regarding potentially applicable bioassessment techniques.

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[4] Charles Stephen, EPA, Duluth, Minnesota, personal communication. April 3, 1990.

8.7 SUMMARY AND CONCLUSIONS

This baseline risk assessment addressed the potential impacts on human health and the environment associated with Carroll Island in the absence of remedial actions. The hydrogeologic field investigation initiated by USGS in October 1986 and summarized in USGS (1990) is the source of sampling data considered in this risk assessment. The data for this assessment were obtained directly from the USATHAMA database (IRDMS).

Inorganic chemicals are the predominant chemicals of potential concern in groundwater and surface water, although there is some uncertainty associated with this determination, because no site-specific background concentration data were available. Few organic chemicals were detected in the surficial aquifer groundwater, and none were detected in the confined aquifer. Low levels of volatile organic chemicals were detected in surface water at eastern Carroll Island, and thiodiglycol, a hydrolysis product of mustard, was detected in the Chesapeake Bay near the Lower Island disposal site. Chemicals of potential concern could not be selected for soil/sediment, because no data are available at this time. In addition to the chemicals of potential concern selected for groundwater and surface water using the available sampling data, VX, mustard, adamsite, and chloroacetophenone could be present at Carroll Island and may be of potential concern regarding possible exposures and risks.

8.7.1 HUMAN HEALTH RISK ASSESSMENT SUMMARY

The primary pathways through which humans could be exposed to chemicals of potential concern in the Carroll Island study area under current use is via direct contact with chemical agents (e.g., mustard, VX) or drums of supertropical bleach potentially present in surface soil at eastern Carroll Island. Hunters and trappers are the only populations currently at risk for these types of exposures. No other potential exposure pathways are likely to result in significant exposure under current land-use conditions. The only human exposure pathways potentially complete under future land-use conditions are (1) ingestion of on-site groundwater by workers at Carroll Island, (2) inhalation and dermal contact with chemicals in groundwater by workers during use of the groundwater, and (3) exposure to white phosphorus-containing munitions or unexploded ordnance during excavation by future workers. Ingestion of groundwater was the only pathway evaluated quantitatively.

The estimated human health risks associated with these pathways are discussed below.

Current Land-Use

- Hunters or trappers disturbing drums of supertropical bleach at the EPG dump site are at risk of burns. Hunters who encounter mustard at the Lower Island disposal site may suffer incapacitating or lethal effects from exposure to mustard. Hunters at eastern Carroll Island also could encounter VX, adamasite, and chloroacetophenone. VX is a lethal chemical agent, and adamsite and chloroacetophenone are incapacitating agents that could cause a variety of nonlethal effects.

Future Land-Use

- The upper-bound excess lifetime cancer risks for ingestion of groundwater from the shallow aquifer by future workers were $1x10^{-6}$ for the Bengies Point Road dump site and the service area/dredge spoils site due to methylene chloride, and $7x10^{-8}$ for eastern Carroll Island due to 1,2-dichloroethane. Methylene chloride, a common laboratory contaminant, may not be present in groundwater at Carroll Island, although no blank data were avaialble to make this determination. No carcinogens were detected in the shallow aquifer at the EPG dump site or in the confined aquifer for all areas at Carroll Island.

- Hazard Indices for ingestion of surficial aquifer groundwater by future workers exceeded 1 due to thallium for the EPG dump site, the Bengies Point Road dump site, the service area/dredge spoils site, and eastern Carroll Island. The Hazard Index was less than 1 for future workers ingesting groundwater from the confined aquifer for all area. There is some uncertainty associated with the selection of thallium as a chemical of potential concern, because it is a naturally occuring metal and could be present at the site at background concentrations. However, no site-specific background data were available to evaluate the site-relatedness of thallium.

- Additional worker exposures to chemicals in groundwater via inhalation or dermal contact are not likely to add significantly to ingestion risks because workers are not likely to engage in activities that could result in significant inhalation or dermal exposures (e.g., showering or bathing).

- Future workers at eastern Carroll Island could encounter unexploded ordnance containing white phosphorus and high-explosives during excavation or other activities involving disturbance of soil. The human hazards from fire and explosion include burns, dismemberment, and death.

8.7.2 ECOLOGICAL ASSESSMENT SUMMARY

Potential ecological impacts were evaluated for aquatic and terrestrial wildlife at Carroll Island. The scope of the ecological assessment was limited by the availability of chemical data for potential exposure media. Surface water was the only potential ecological exposure medium for which sampling data were available, and many of the surface water samples collected were from surface waters that most likely provide habitat for invertebrates and amphibians only. Therefore, the principal receptors for this assessment were limited to aquatic invertebrates, amphibians, and the terrestrial species that feed on them. The sandpiper was the terrestrial species selected for evaluation. Potential impacts in aquatic and terrestrial wildlife that inhabit or feed in the marshes of Carroll Island or in adjacent Saltpeter Creek and the Chesapeake Bay cannot be evaluated with any degree of confidence because the few surface water samples collected from these waters are not sufficient to characterize potential ecological impacts in these areas.

The results of the ecological assessment are as follows:

- Aquatic life inhabiting the seasonal pools and other surface waters at Carroll Island are probably being impacted to some extent by the inorganic chemicals present in these waters.

- Sandpipers feeding in the surface waters near the Bengies Point Road dump site or in eastern Carroll Island could be impacted by elevated dietary levels of metals.

8.7.3 CONCLUSIONS OF THE RISK ASSESSMENT

Past activities at Carroll Island have resulted in contamination of groundwater and surface water of the area. The extent of contamination in other media at the site is currently unknown. Few human health exposure pathways exist under current land-use conditions; only potential acute exposures to chemical agents or large quantities of supertropical bleach are associated with potentially significant human health hazards. Additional human health risks could be possible if human use of Carroll Island changes in the future. In particular, use of groundwater from the area might be associated with human health risks, although the site-relatedness of the chemicals driving these risks (i.e., methylene chloride and thallium) is questionable at the present time.

Aquatic life in seasonal ponded areas and other surface water habitats at Carroll Island could be impacted from exposure to metals. Impacts associated with seasonal surface waters are unlikely to significantly affect the seasonal aquatic populations of Carroll Island (e.g, insects, frogs), given the wide availability of more suitable habitat across the island. Similar effects in the marshes of Carroll Island or in adjacent Saltpeter Creek and the Chesapeake Bay could result in more significant ecological impacts. However, this cannot be evaluated because samples collected from these waters are not sufficient to characterize potential ecological impacts in these areas.

Sandpipers and other shorebirds feeding near the EPG dump site or in eastern Carroll Island could be impacted from dietary exposures to metals. Given the size of the eastern Carroll Island study area, it potentially could support a large number of spotted sandpipers, as this species has a relatively small home range area. Thus, toxic dietary levels of metals across this area could impact a significant number of sandpipers, resulting in local population impacts. Furthermore, impacts on the population of sandpipers using Carroll Island could contribute to cumulative impacts associated with APG as a whole.

Additonal data are needed for a more complete evaluation of the potential human health and ecological impacts associated with the Carroll Island study area.

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9.0 GRACES QUARTERS RISK ASSESSMENT

This chapter evaluates potential impacts on human health and the environment associated with the Graces Quarters study area in the absence of remedial (corrective) actions. The hydrogeological investigation conducted by USGS (1990) is the primary source of sampling data considered in this risk assessment. The data from this study were obtained from the USATHAMA database (IRDMS). This study was selected for use in this risk assessment because it was the most recent and comprehensive study conducted at Graces Quarters. As part of this investigation, data were collected during two sampling rounds in 1988 and 1989. The laboratory that analyzed the 1988 samples may have falsified sampling results. Thus, no data from the 1988 sampling round were included in this assessment. It should be noted, however, that no field or trip blank samples were available for use in validating the sampling results of the USGS study.

Monitoring results from groundwater and surface water only were available from the USGS (1990) study. Soil and sediment samples were collected during the study conducted by USGS, but monitoring results were not available during the preparation of this report. Therefore, the extent of contamination and potential exposure to soil and sediments could not be quantitatively evaluated in this assessment. Limited monitoring data obtained from previous studies conducted by USATHAMA from 1976 to 1979 are summarized in Chapter 3.

The USGS study and other investigations conducted to date have not completely characterized the nature and extent of contamination at Graces Quarters. Therefore, this risk assessment should be considered largely preliminary and is intended as an initial step in the overall risk assessment process for Graces Quarters.

This assessment follows the general methodology outlined in Chapter 4 of this report and is organized into five primary sections:

- Section 9.1 Background Information
- Section 9.2 Selection of Chemicals of Potential Concern
- Section 9.3 Human Health Risk Assessment
- Section 9.4 Ecological Assessment
- Section 9.5 Uncertainties
- Section 9.6 Principal Data Gaps
- Section 9.7 Summary and Conclusions
- Section 9.8 References

9.1 BACKGROUND INFORMATION[1]

Graces Quarters is a testing area that was used for chemical agent testing from the late 1940s until 1971. Solid waste was buried in pits at a disposal area from the mid-1940s to the early 1970s. Other areas were also used as dumps for buried solid waste during this time.

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[1] Information summarized in this section was obtained primarily from USGS (1990) and AEHA (1989).

Graces Quarters is located on the west side of APG. It is a peninsula bounded by the Gunpowder River to the east, Dundee Creek to the west, Saltpeter Creek to the south, and the Hammerman Area of Gunpowder State Park to the north (see Figure 9-1). It is approximately 476 acres in size. The elevation of the peninsula ranges from a high point of 40 feet above sea level to marshy, low-lying areas in the south. There is a cliff on the eastern shore that is over 30 feet high. Much of Graces Quarters is wooded with some open fields and marshy areas. The only structure on the site is a U.S. Federal Emergency Management Agency (FEMA) tower that was used as an emergency radio transmitter from 1970 to 1988. The FEMA tower is currently not used.

Graces Quarters is not open to the public, and access is restricted by a fence around the whole area.

Chemical agent and biological simulant testing was performed at Graces Quarters from the late 1940s until 1971. Testing activities were similar to those performed on Carroll Island except the amount of testing was much less on Graces Quarters and the testing facilities were not as permanent or extensive. During the period of July 1964 to December 1971, VX, Telvar, sarin, soman, EA 3990 (an experimental chemical agent), and CS-1 were released in testing activities. The types of materials tested or released at Carroll Island and Graces Quarters include chemical warfare agents and their associated decontamination agents, solvents and petroleum products, herbicides, and insecticides. The types of chemical warfare agents tested include blister, nerve, incapacitating, riot control, and smokes.

The principal blister agent tested was mustard. Nerve agents tested in the study areas include tabun, sarin, soman, and VX. The incapacitating agent tested was BZ, and the riot control agents include adamsite, chloroacetophenone (CN), and o-chlorobenzylidene malonitrile (CS). Smokes tested include white phosphorus (WP), triethylaluminum (TEA), and sulfur trioxide and chlorosulfonic acid mixture (FS). The decontaminating agents used after chemical agent testing include calcium hypochlorite (HTH), super tropical bleach (STB), sodium hydroxide, decontaminating agent-noncorrosive (DANC), DS-2, and carbon tetrachloride.

From 1959 to 1971 insecticides mixed with fuel oil were applied to Carroll Island and Graces Quarters each summer. Malathion was used from 1959 to 1969 and Dibrom 14 was used after 1969.

Solvents and petroleum products were used at both study areas. Solvents were used for equipment maintenance and cleaning, while petroleum products were used as additive mixtures for some testing and decontamination practices.

Most of the chemical agent tests were confined to the primary test area. Smaller amounts of testing were done at the secondary test area and at the three HD (distilled mustard) test annuli. The 1983 Environmental Survey (USATHAMA 1983) reported an unsubstantiated rumor that the area was used as a site for chemical agent disposal during the 1940s. It was confirmed that chemical agents were disposed of in some waste burial pits on the eastern shore of the peninsula, the primary test area, and the HD test annuli. Solid waste was buried in the disposal area, the northern and southern dumps, and the Graces Quarters dump. A list of everything believed to have been disposed of at Graces Quarters is presented in Table 9-1. There are nine possible source areas located in the Graces Quarters study area. Figure 9-1 shows the approximate location of each of these areas. They are discussed below.

<u>Graces Quarters Disposal Area</u>. From the mid 1940s to the early 1970s solid wastes from chemical agent test operations were buried in pits at the disposal area. Wastes disposed of in the pits include munitions fragments and remains, unusable sampling equipment, empty containers, and

TABLE 9-1

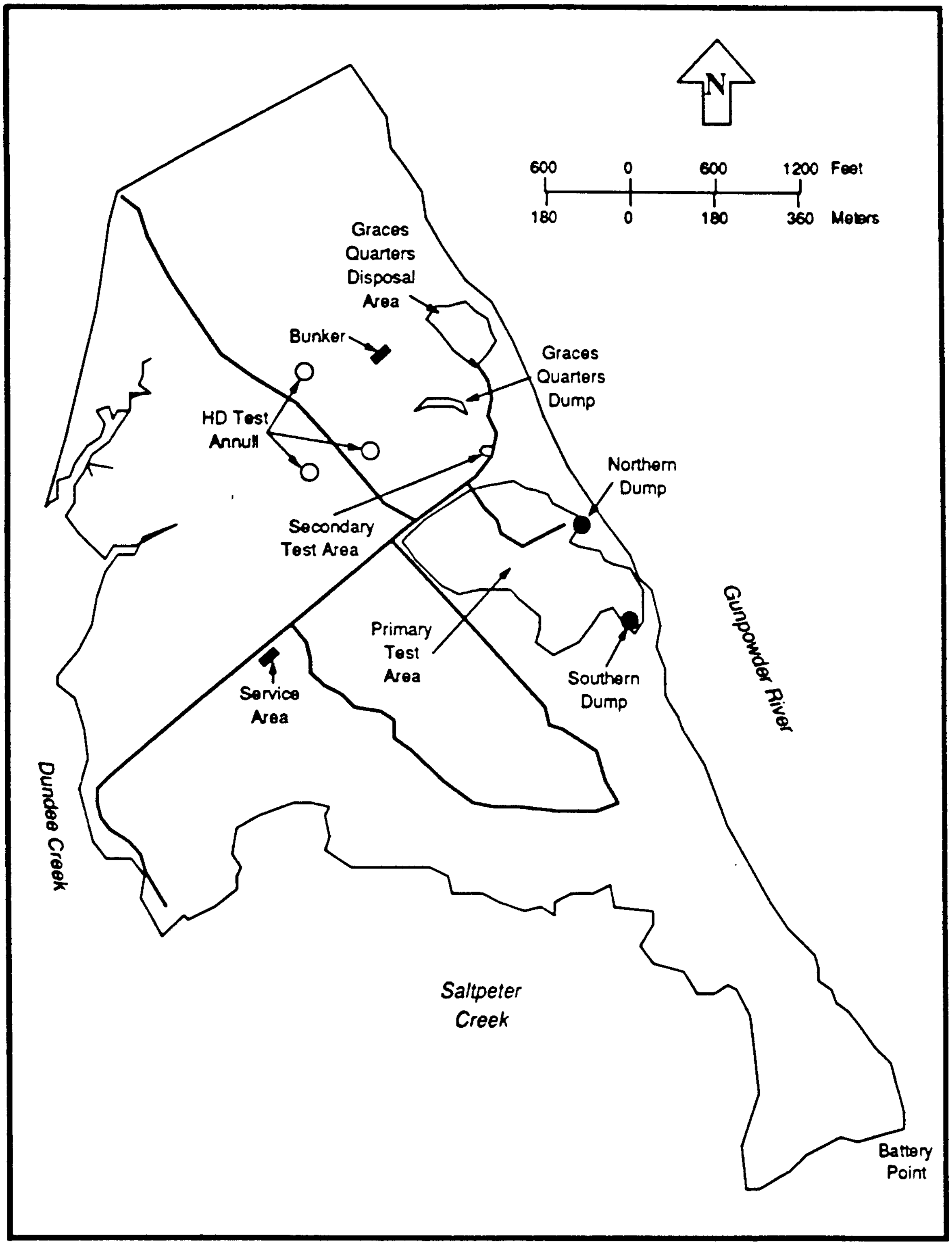
PRINCIPAL COMPOUNDS DISPOSED OF AND/OR USED AT
GRACES QUARTERS (a)

Group	Chemical Compound (Acronym) (b)
Lethal Chemical Agents	Distilled Mustard (HD) VX Sarin (GB) Soman (GD) Tabun (GA) EA 3990
Incapacitating Agents	o-Chlorobenzylidene Malononitrile (CS) Adamsite (DM) Chloroacetophenone (CN) 3-Quinuclidinyl Benzilate (BZ)
Decontaminating Agents	Calcium Hypochlorite (HTH) Supertropical Bleach (STB) Sodium Hydroxide (NaOH) DS-2 Decontaminating agent-noncorrosive (DANC)
Smoke/Incendiary Materials	Fuming Nitric Acid White Phosphorus (WP) Triethylaluminum (TEA) Sulfur Trioxide and Chlorosulfonic Acid mixture (FS)
Solvents	Chloroform Carbon Tetrachloride 1,1,2,2-Tetrachloroethane [major component of DANC] Trichlorofluoromethane
Pesticides	Malathion Telvar Dibrom 14

(a) Information obtained primarily from USGS (1990) and AEHA (1989).
(b) See Glossary of Acronyms and Abbreviations for complete chemical name if not given in this table.

Figure 9-1

Graces Quarters Study Area



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similar wastes. There is no indication that bulk chemical wastes were disposed of here. Magnetometry reveals buried metal at three sites in the disposal area. From the 1950s until the early 1970s, items contaminated with lethal chemical agents were chemically decontaminated before being disposed of in the pits. Items contaminated with nonlethal agents such as CS or BZ also may have been disposed of in the pits. The site still shows evidence of disposal activities such as scattered debris and depressions in the ground where burial took place.

Graces Quarters Dump. There is limited historical information on Graces Quarters dump. Magnetometer surveys indicate the presence of buried material, and empty bleach cans are visible on the ground surface. Trees appear to have been disposed of southwest of the dump site. There is also some mounding of soil thought to be from construction work.

Primary Test Area. The primary test area was used as a test site from the late 1940s to the early 1970s. In the early 1950s, approximately 10 annular rings were used for testing, and several small structures were built. Between 1960 and 1970, airplanes used for decontamination studies were parked in the area. By 1970, there was also a water-filled trench near what is now the southern dump site.

Secondary Test Area. Very little information is available on past uses of the secondary test area. It probably was not used extensively, and, except for a few scattered supertropical bleach (STB) cans, there is little current surficial evidence of testing.

HD Test Annuli. The HD test annuli were probably built in 1951 or 1952. The annuli were used in decontamination studies involving distilled mustard (HD), VX, and fuming nitric acid. Testing before 1964 was poorly documented, although it is thought that most testing occurred then. Around 1971, the northernmost annulus was removed for the construction of a FEMA radio tower. Two annuli still remain.

Bunker. The bunker was built out of timber and sand bags in the late 1940s or early 1950s and destroyed in the late 1950s. The remaining depression was never designated as a disposal site. Metal was not detected in the depression.

Northern Dump. The northern dump in the test area was located during a survey field reconnaissance. Research did not produce any historical information on this dump. There appears to have been no burial of wastes at the northern dump. Debris found at the dump included seven empty 55-gallon drums, several empty decontamination tanks (which contained DS-2), one empty DANC container, empty STB containers, discarded personal protective equipment (PPE), downed power poles, and unidentified pieces of lab or field equipment.

Southern Dump. The southern dump was also located during a survey field reconnaissance, and no historical information on this dump could be found. The area appears to have been used for disposal of unusable STB and STB containers as well as some building debris. It is likely that only junk and unusable decontaminating material was dumped in this area.

Service Area. There is no historical information about this site. Its use was probably similar to that of Carroll Island Service Area, which was used for equipment maintenance and minor laboratory work. Currently, the Graces Quarters Service Area contains a quonset hut and a holding tank. According to a sign on the hut, it was a repair facility. Assorted junk dumped in the area includes discarded personal protective equipment and STB cans.

9.2 SELECTION OF CHEMICALS OF POTENTIAL CONCERN

In this section, environmental monitoring data collected by USGS at Graces Quarters are briefly summarized, and chemicals of potential concern selected for further evaluation are listed. As part of the USGS hydrogeological study sampling protocol, groundwater and surface water samples were analyzed only for inorganic chemicals and volatile and semivolatile compounds. It should be noted, however, that these samples were not analyzed for chemical agents, agent degradation products, or radioactivity. Chemical agents released at Graces Quarters include nearly 200 pounds of VX (an anticholinesterase agent), 9 pounds of sarin (GB), and 1 pound of soman (GD). In addition, 50 pounds of the herbicide Telvar were sprayed in test areas at Graces Quarters in order to keep the areas free of vegetation. Several mustard gas testing areas (HD test annuli) also are located at Graces Quarters. The extent of groundwater and surface water contamination from the release of these chemicals is not known.

The discussions are organized below by environmental medium.

9.2.1 GROUNDWATER

There are two distinct aquifer systems at Graces Quarters: a surficial aquifer and a lower confined aquifer. The surficial aquifer is confined below by a dense clay layer. The depth to the top of the surficial aquifer ranges from 5 to 40 feet below the ground surface. The surficial aquifer consists of a series of perched aquifers formed by discontinuous clay lenses. The thickness of the surficial aquifer ranges from 0 to 20 feet. Groundwater flow direction in the surficial aquifer tends to follow the topographic relief of the site (i.e., to the south and southeast). The shapes of the clay lenses, however, may result in localized groundwater flow in directions that differ from topographic relief (i.e., to the north). The confined aquifer is located approximately 60-100 feet below the ground surface (USGS 1990).

Twenty-four monitoring wells were installed in the surficial aquifer, and five wells were installed in the confined aquifer as part of the USGS (1990) hydrogeological investigation. The monitoring wells were installed in the northern portion of Graces Quarters in areas where waste handling and agent testing took place. In this report, monitoring results from this investigation are summarized by aquifer (i.e., surficial and confined).

For Graces Quarters, no site-specific background samples were available to characterize natural levels of inorganic compounds in groundwater. The upper end of the range of national concentrations of inorganic chemicals naturally occurring in groundwater, as reported in Walton (1985), were used in this assessment for the purpose of determining the potential site-relatedness of inorganic chemicals in groundwater.

9.2.1.1 Surficial Aquifer

Organic chemicals detected in the surficial aquifer at Graces Quarters are summarized in Table 9-2. Eleven organic chemicals were detected in the surficial aquifer: benzene, bis(2-ethylhexyl)phthalate, carbon tetrachloride, chloroform, 1,1-dichloroethene, 1,2-dichloroethene, ethyl benzene, toluene, 1,1,2,2-tetrachloroethane, trichloroethene, and xylenes (total). The majority of the organic chemicals detected in the surficial aquifer were chlorinated aliphatic compounds and petroleum-related compounds (i.e., benzene, ethyl benzene, toluene, and xylenes [total]). These organic chemicals

TABLE 9-2

SUMMARY OF CHEMICALS DETECTED IN SURFICIAL AQUIFER GROUNDWATER AT GRACES QUARTERS (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Background Concentration (e)
Organic Chemicals:			
* Benzene (C6H6)	1 / 24	0.9	NA
* Carbon Tetrachloride (CCL4)	3 / 24	0.6 - 5,710	NA
* Chloroform (CHCL3)	4 / 24	0.9 - 103	NA
* 1,1-Dichloroethene (11DCE)	1 / 24	0.6	NA
* 1,2-Dichloroethene [Total] (12DCE)	1 / 24	3.4	NA
* Ethyl Benzene (ETC6H5)	1 / 24	3.2	NA
* bis(2-Ethylhexyl)phthalate (B2EHP)	3 / 8	5.4 - 8.7	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	2 / 22	11.7 - 1,940	NA
* Toluene (MEC6H5)	1 / 24	12.7	NA
* Trichloroethene (TRCLE)	2 / 24	9.1 - 952	NA
* Xylenes [Total] (XYLEN)	2 / 24	0.8 - 17	NA
Inorganic Chemicals:			
* Aluminum (AL)	10 / 24	191 - 2,110	100
Barium (BA)	24 / 24	10.8 - 82.8	100
Calcium (CA)	24 / 24	1,300 - 61,000	1,000,000
Chloride (CL)	22 / 23	2,570 - 77,000	1,000,000
Chromium (CR)	2 / 24	8.0 - 30.9	100
Copper (CU)	22 / 24	8.4 - 60.7	100
* Iron (FE)	16 / 24	48.5 - 21,900	10,000
Lead (PB)	9 / 24	1.5 - 77.2	100
Magnesium (MG)	24 / 24	534 - 8,990	1,000,000
* Manganese (MN)	24 / 24	5.6 - 861	100
* Nickel (NI)	3 / 24	77.6 - 272	100
Nitrite/Nitrate (NIT) (f)	20 / 24	10.8 - 4,300	10,000
Potassium (K)	18 / 24	606 - 11,300	10,000
* Silver (AG)	1 / 24	5.0	1.0
Sodium (NA)	24 / 24	2,410 - 61,000	1,000,000
Sulfate (SO4)	22 / 23	10,700 - 81,700	1,000,000
* Thallium (TL)	1 / 24	111	1.0
* Zinc (ZN)	15 / 24	22.7 - 344	100

(a) Samples: Q01, Q02, A03, Q05, Q06, Q07, Q08, Q09A, Q10, Q11, Q12, Q13, Q14, Q15, Q16B, Q18A, Q20A, Q21, Q22, Q24, Q25, Q26, and Q28.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Values reported for metals are dissolved concentrations.
(e) Background concentrations from Walton (1985). Values reported are dissolved concentrations.
(f) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

typically were detected only in one or two monitoring wells. The detected concentrations of these chemicals were below a concentration of 20 µg/L in all monitoring wells with the exception of monitoring well Q14. The maximum concentrations of carbon tetrachloride (5,710 µg/L), chloroform (103 µg/L), trichloroethene (952 µg/L), and 1,1,2,2-tetrachloroethane (1,940 µg/L) were detected in this monitoring well. Monitoring well Q14 is screened in the surficial aquifer in the center of the primary test area. Chloroform is possibly present as a decontamination by-product of mustard and VX. A soil gas survey conducted by Northeast Research Institute Inc. (NERI 1990) in the surficial aquifer zone at Graces Quarters indicates that the center of one of the volatile organic plumes at the primary test area may be located approximately 300 feet north of well Q14. Monitoring wells installed potentially downgradient of Q14 (i.e., Q16A and Q20A) had no detected concentrations of these four chemicals. The soil gas survey (NERI 1990), however, indicates that another plume of volatile organic chemicals may be present approximately 200 feet southwest of well Q16A. Monitoring well Q08, located at the northern dump area, had detected concentrations of benzene, ethyl benzene, toluene, and xylenes (total), which indicates a possible source of petroleum contamination near this well (e.g., gasoline). In addition, the petroleum compound tridecane, which is a tentatively identified compound (TIC), was detected once at monitoring well Q03 downgradient of the northern dump site. Results of the soil gas survey (NERI 1990) also indicate the presence of petroleum contamination in the surficial aquifer around the primary test site area.

Inorganic chemicals detected in the surficial aquifer at Graces Quarters are summarized in Table 9-2. Of the 18 inorganic chemicals detected in filtered groundwater samples, barium, calcium, chloride, chromium, copper, lead, magnesium, sodium, and sulfate were determined to be within background concentrations (Walton 1985). Therefore, these chemicals were not selected as chemicals of potential concern. Levels of potassium appeared to be slightly elevated above background. This inorganic chemical, however, was not selected as inorganic chemicals of concern because it is of low toxicity to humans and aquatic and terrestrial wildlife. The remaining inorganic chemicals detected in the surficial aquifer above background concentrations (aluminum, iron, manganese, nickel, silver, thallium, and zinc) were selected as chemicals of potential concern. It should be noted, however, that silver and thallium were detected infrequently (i.e., in fewer than 5% of the samples). The highest concentrations of aluminum, nickel, and zinc were detected in monitoring well Q06, which is not suspected of being directly downgradient of any suspected source areas. Monitoring well Q15 was the only monitoring well with elevated concentrations of iron and thallium. This monitoring well is located downgradient of a decontamination trench near the southern dump site. Monitoring well Q20A has the only detected concentration of silver. This monitoring well is located along the service road farthest downgradient from the primary test area. No disposal occurred directly in this area suggesting that the presence of silver may be due to natural minerals.

9.2.1.2 Confined Aquifer

Organic chemicals detected in the confined aquifer at Graces Quarters are summarized in Table 9-3. The five organic chemicals detected in the confined aquifer groundwater were also detected in the surficial aquifer. They are bis(2-ethylhexyl)phthalate, chloroform, 1,2-dichloroethene, 1,1,2,2-tetrachloroethane, and trichloroethene. These chemicals were detected infrequently and at low concentrations (below 5 µg/L). Thus, fewer organic compounds were detected in the confined aquifer at much lower concentrations as compared to the surficial aquifer. Four of the five chemicals detected in the confined aquifer were chlorinated aliphatic compounds. All of these compounds, with the exception of chloroform, were detected only in monitoring well Q16A, which is located downgradient of the primary test area. Chloroform was detected in monitoring well Q18B downgradient of the southern ring of the HD test annuli. It should be noted, however, that monitoring wells were not installed in the

TABLE 9-3

SUMMARY OF CHEMICALS DETECTED IN CONFINED AQUIFER GROUNDWATER AT GRACES QUARTERS (a)

(Concentrations reported in ug/L)

Chemical (b)	Frequency of Detection (c)	Range of Detected Concentrations (d)	Background Concentration (e)
Organic Chemicals:			
* Chloroform (CHCL3)	1 / 5	1.5	NA
* 1,2-Dichloroethene [Total] (12DCE)	1 / 5	1.2	NA
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 3	4.2	NA
* 1,1,2,2-Tetrachloroethane (TCLEA)	1 / 5	3.2	NA
* Trichloroethene (TRCLE)	1 / 5	0.4	NA
Inorganic Chemicals:			
Barium (BA)	5 / 5	8.9 - 12.4	100
Calcium (CA)	5 / 5	1,670 - 10,700	1,000,000
Chloride (CL)	4 / 5	3,180 - 16,700	1,000,000
Copper (CU)	3 / 5	5.9 - 34.9	100
Iron (FE)	3 / 5	1,250 - 5,710	10,000
Lead (PB)	3 / 5	0.9 - 11.2	100
Magnesium (MG)	5 / 5	690 - 2,770	1,000,000
* Manganese (MN)	5 / 5	12.8 - 276	100
Nitrite/Nitrate (NIT) (f)	3 / 5	23.2 - 1,900	10,000
Potassium (K)	4 / 5	557 - 2,260	10,000
* Silver (AG)	1 / 5	3.1	1.0
Sodium (NA)	5 / 5	2,260 - 9,060	1,000,000
Sulfate (SO4)	3 / 5	11,600 - 29,100	1,000,000
Zinc (ZN)	3 / 5	44.3 - 69.2	100

(a) Samples: Q9B, Q16A, Q18B, Q19A, and Q20B.
(b) USATHAMA chemical codes listed in parentheses.
(c) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(d) Values reported for metals are dissolved concentrations.
(e) Background concentrations from Walton (1985). Values reported are dissolved concentrations.
(f) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrite/nitrate.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

confined aquifer near monitoring well Q14, which had the maximum detected concentrations of organic chemicals in the surficial aquifer.

Inorganic chemicals detected in the confined aquifer at Graces Quarters are summarized in Table 9-3. Of the 14 inorganic chemicals detected in filtered groundwater samples, barium, calcium, chloride, chromium, copper, iron, lead, magnesium, nitrate/nitrite, sodium, sulfate, and zinc were determined to be within background concentrations (Walton 1985). Therefore, these chemicals were not selected as chemicals of potential concern. The remaining inorganic chemicals detected in the confined aquifer (manganese and silver) were selected as chemicals of potential concern although the concentrations of silver were very close to the background concentrations used for comparison. The maximum detected concentrations of manganese and silver were found in monitoring wells Q18B, Q09B, and Q16A, respectively. Monitoring well Q18B is located downgradient of the HD test annuli. Monitoring well Q09B is located downgradient of the northern disposal area, while monitoring well Q16A is located downgradient of the primary test site.

9.2.2 SURFACE WATER

Approximately 80% of Graces Quarters is surrounded by surface water. The Gunpowder River borders Graces Quarters to the northeast, and Dundee Creek and Saltpeter Creek border Graces Quarters to the southwest and south, respectively.

Given the hydrogeology of Graces Quarters, it is possible that groundwater from the area may discharge to all of these water bodies. As previously discussed, groundwater generally flows to the south and southeast along the topographic relief of the site. Chemicals of potential concern present in groundwater would thus tend to move in this direction, potentially impacting Dundee Creek and Saltpeter Creek. As part of the USGS (1990) hydrogeological investigation, no surface water samples were collected from Dundee Creek or Saltpeter Creek. It does not appear, however, that groundwater would have any significant impact on these creeks, given the distance between them and the disposal areas (the disposal and test areas are located along the northeast border near Gunpowder River), the lack of contamination found in monitoring wells installed farthest downgradient from the source areas, and the potential dilution of the chemicals in these creeks.

As previously discussed, groundwater in the surficial aquifer may flow in directions other than topographic relief. Thus, contaminated surficial groundwater may discharge to the Gunpowder River from nearby disposal and test areas. In fact, several groundwater discharge points were noted along the cliff face at Graces Quarters (USGS 1990). Surface water run-off and erosion along the cliff face also may impact the water quality of the Gunpowder River. As part of the USGS (1990) hydrogeological investigation, several surface water samples were collected from the Gunpowder River near the northern disposal area and the southern disposal area at Graces Quarters.

No perennial surface water bodies are located at Graces Quarters. During the spring months, however, small ponds may be formed when ditches and depressions collect surface water runoff during periods of heavy precipitation. These surface water bodies may be important breeding grounds for amphibians, reptiles, and arthropods at Graces Quarters. Samples were collected from these ponds in the northern disposal area (northern dump site, Graces Quarters dump, and bunker) and southern disposal area (southern dump site and decontamination trenches).

No site-specific background samples were available to characterize the natural levels of inorganic compounds in surface water at Graces Quarters. The background concentrations obtained from tributaries to the Gunpowder River and Bush River were used to identify inorganic chemicals that may be present because of site activities (data obtained from Foster Branch, Otter Point Creek, and Cranberry Run from the STORET database, EPA Region III) (see Chapter 4 for a discussion of the methodology for selecting chemicals of concern using these data).

Monitoring results for the northern disposal area (on-site ditches and the Gunpowder River) and southern disposal area (on-site ditches and the Gunpowder River) are presented below.

9.2.2.1 Northern Disposal Area

As shown in Table 9-4, bis(2-ethylhexyl)phthalate was the only organic chemical detected in on-site surface water. Bis(2-ethylhexyl)phthalate was detected at low levels in surface water at the Graces Quarters dump, bunker, and along the service road. This chemical is a common laboratory contaminant, and therefore may not be site related (no blanks were available to evaluate this). However, the chemical may be site-related given that phthalates were reportedly used at Graces Quarters as thickening agents in chemical munitions and agents as part of tests conducted by Dougway Proving Ground from 1968 to 1972. No organic compounds were detected in the Gunpowder River near the northern disposal area.

Inorganic chemicals detected in on-site surface water in the northern disposal area at Graces Quarters are summarized in Table 9-4. Of the 14 inorganic chemicals detected in unfiltered on-site surface water samples, barium, chloride, chromium, magnesium, manganese, nitrite/nitrate, sodium, sulfate, and zinc were determined to be within background concentrations. Therefore, these chemicals were not selected as chemicals of potential concern. Levels of calcium and potassium appeared to be slightly elevated above background. These chemicals, however, have low toxicity to humans and aquatic and terrestrial wildlife. Therefore, calcium and potassium were not selected as chemicals of concern. The remaining inorganic chemicals detected in on-site surface water (aluminum, copper, and iron) were selected as chemicals of potential concern. The maximum detected concentrations of these chemicals were found near the northern dump site (samples GQSW10, GQSW11).

Inorganic chemicals detected in Gunpowder River at the northern disposal area at Graces Quarters are summarized in Table 9-4. Of the 16 inorganic chemicals detected in unfiltered Gunpowder River samples, barium, calcium, chromium, manganese, nitrite/nitrate, sulfate, and zinc were determined to be within background concentrations. Therefore, these chemicals were not selected as chemicals of potential concern. Levels of chloride, magnesium, potassium, and sodium appeared to be slightly elevated above background. These chemicals, however, have low toxicity to humans and aquatic and terrestrial wildlife, so they were not selected as chemicals of potential concern. The remaining inorganic chemicals detected in the Gunpowder River (aluminum, cadmium, copper. iron, and nickel) were selected as chemicals of potential concern. In general, lower concentrations of inorganics were found in the Gunpowder River near the northern dump site than in on-site ditches. However, cadmium and nickel, which were not detected in on-site surface water, were detected in the Gunpowder River at concentrations above background. Cadmium and nickel were detected in the sample farthest from the northern disposal area; therefore, the northern disposal area may not be a source of these chemicals. The maximum concentrations of aluminum and iron were found in the surface water sample closest to the northern disposal area, which indicates that it may be a potential source of these chemicals.

TABLE 9-4

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AT GRACES QUARTERS
NOTHERN DISPOSAL AREA

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
ON-SITE SURFACE WATER (e)			
Organic Chemicals:			
* bis(2-Ethylhexyl)phthalate (B2EHP)	3 / 5	4.5 - 4.7	NA
Inorganic Chemicals:			
* Aluminum (AL)	4 / 5	474 - 13,100	<10
Barium (BA)	5 / 5	13 - 72.2	74
Calcium (CA)	5 / 5	2,570 - 29,000	4,400 - 14,000
Chloride (CL)	2 / 5	2,900 - 2,930	12,000 - 46,000 (f)
Chromium (CR)	1 / 5	16.1	42
* Copper (CU)	5 / 5	8.8 - 30.9	1
* Iron (FE)	5 / 5	254 - 13,300	230 - 2,700 (f)
Magnesium (MG)	5 / 5	1,810 - 4,660	2,000 - 7,100
Manganese (MN)	5 / 5	54.7 - 198	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	4 / 5	13 - 1,700	100 - 5,300
Potassium (K)	3 / 5	1,990 - 4,130	1,000 - 3,000
Sodium (NA)	5 / 5	1,110 - 3,010	6,700 - 21,000
Sulfate (SO4)	3 / 5	11100 - 20,800	7,000 - 21,000 (f)
Zinc (ZN)	4 / 5	34.5 - 75.3	75
GUNPOWDER RIVER (h)			
Inorganic Chemicals:			
* Aluminum (AL)	2 / 2	667 - 2,020	10
Barium (BA)	2 / 2	18.2 - 40.8	74
* Cadmium (CD)	1 / 2	12.2	<1
Calcium (CA)	2 / 2	11,100 - 11,600	4,400 - 14,000
Chloride (CL)	2 / 2	71,000 - 88,000	12,000 - 46,000 (f)
Chromium (CR)	2 / 2	9.6 - 16.5	42
* Copper (CU)	2 / 2	15.5 - 31.2	1
* Iron (FE)	2 / 2	1,110 - 4,020	230 - 2,700 (f)
Magnesium (MG)	2 / 2	7,940 - 8,700	2,000 - 7,100
Manganese (MN)	2 / 2	41.3 - 59	100 - 700 (f)
* Nickel (NI)	1 / 2	53.1	6
Nitrite/Nitrate (NIT) (g)	2 / 2	980 - 990	100 - 5,300
Potassium (K)	2 / 2	3,270 - 4,000	1,000 - 3,000
Sodium (NA)	2 / 2	32,600 - 39,500	6,700 - 21,000
Sulfate (SO4)	2 / 2	14,900 - 17,100	7,000 - 21,000 (f)
Zinc (ZN)	2 / 2	31.7 - 65.6	75

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Total concentrations reported.
(d) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(e) Samples: GQSW4, GQSW6, GQSW9, GQSW10 and GQSW11.
analysis).
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentrations of nitrate/nitrite.
(h) Samples: GQSW1 and GQSW2.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

9.2.2.2 Southern Disposal Area

As shown in Table 9-5, bis(2-ethylhexyl)phthalate was the only organic chemical detected (and only at a low level) in on-site surface water (decontamination pits) and the Gunpowder River at the southern disposal area. As previously discussed, although this chemical is a potential laboratory contaminant, phthalates were reportedly used at Graces Quarters as thickening agents in chemical munitions and agents as part of tests conducted by Dougway Proving Ground from 1968 to 1972.

Inorganic chemicals detected in on-site surface water in the southern disposal area at Graces Quarters are summarized in Table 9-5. Of the 14 inorganic chemicals detected in unfiltered on-site surface water samples, barium, calcium, chromium, nitrite/nitrate, potassium, sodium, and zinc were determined to be within background concentrations. Therefore, these chemicals were not selected as chemicals of potential concern. Levels of chloride, magnesium, and sulfate appeared to be slightly elevated above background. Because these chemicals have low toxicity to humans and aquatic and terrestrial wildlife, they were not selected as chemicals of concern. The remaining inorganic chemicals detected in on-site surface water (aluminum, copper, iron, and manganese) were selected as chemicals of potential concern. The maximum detected concentrations of copper, iron, and manganese were found near the southern dump site. The maximum detected concentration of aluminum was found in the decontamination trenches.

Inorganic chemicals detected in the Gunpowder River at the southern disposal area at Graces Quarters are summarized in Table 9-5. Of the 13 inorganic chemicals detected in the one unfiltered Gunpowder River sample, barium, calcium, iron, manganese, nitrite/nitrate, and sulfate were determined to be within background concentrations. Therefore, these chemicals were not selected as chemicals of potential concern. Levels of chloride, magnesium, potassium, and sodium appeared to be slightly elevated above background, but since they have low toxicity to humans and aquatic and terrestrial wildlife, they were not selected as chemicals of potential concern. The remaining inorganic chemicals detected in the Gunpowder River (aluminum, cadmium, and copper) were selected as chemicals of potential concern. Aluminum and copper, which were present at similar concentrations in on-site ditches and the Gunpowder River, were selected as chemicals of potential concern.

9.2.3 SUMMARY OF CHEMICALS OF CONCERN

Chemicals of potential concern identified for groundwater and surface water are summarized in Table 9-6. The hydrogeological investigation conducted by USGS (1990) characterized the extent of groundwater contamination in the surficial aquifer and the confined aquifer. Groundwater samples were analyzed for volatile and semivolatile organic compounds, and dissolved concentrations of inorganics. Several chlorinated aliphatic compounds, as well as petroleum-related chemicals (i.e., benzene, ethyl benzene, toluene, and xylene), were detected in groundwater. Chloroform, bis(2-ethylhexyl)phthalate, 1,2-dichloroethene (total), 1,1,2,2-tetrachloroethane, and trichloroethene were the only organic chemicals detected in both the surficial aquifer and the confined aquifer, although only trace levels of these chemicals were found in the confined aquifer. Relatively low levels were detected in surficial groundwater also; no organic chemical was detected in groundwater at Graces Quarters at a higher concentration than 20 µg/L, with the exception of high concentrations of carbon tetrachloride (5,710 µg/L), chloroform (103 µg/L), trichloroethene (952 µg/L), and 1,1,2,2-tetrachloroethane (1,940 µg/L) detected in monitoring well Q14 screened in the surficial aquifer. This well is installed in the center of the primary test area. Soil gas results (NERI 1990) indicate that the center of the plume may be approximately 200 feet north of this well. The presence of benzene, ethyl benzene, toluene, tridecane, and xylenes (total) in surficial groundwater in the northern dump site areas indicates a

TABLE 9-5

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AT GRACES QUARTERS
SOUTHERN DISPOSAL AREA

(Concentrations reported in ug/L)

Chemical (a)	Frequency of Detection (b)	Range of Detected Concentrations (c)	Range of Background Concentrations (d)
ON-SITE SURFACE WATER (e)			
Organic Chemicals:			
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 2	7.6	NA
Inorganic Chemicals:			
* Aluminum (AL)	2 / 2	478 - 662	<10
Barium (BA)	2 / 2	16.6 - 43	74
Calcium (CA)	2 / 2	6,120 - 10,900	4,400 - 14,000
Chloride (CL)	1 / 2	55,000	12,000 - 46,000 (f)
Chromium (CR)	1 / 2	7.8	42
* Copper (CU)	1 / 2	9.5	1
* Iron (FE)	2 / 2	1,440 - 3,220	230 - 2,700 (f)
Magnesium (MG)	2 / 2	1,430 - 7,300	2,000 - 7,100
* Manganese (MN)	2 / 2	600 - 2,400	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	2 / 2	13.2 - 13.4	100 - 5,300
Potassium (K)	2 / 2	919 - 1,730	1,000 - 3,000
Sodium (NA)	2 / 2	1,870 - 19,100	6,700 - 21,000
Sulfate (SO4)	1 / 2	22,900	7,000 - 21,000 (f)
Zinc (ZN)	1 / 2	40	75
GUNPOWDER RIVER (h)			
Organic Chemicals:			
* bis(2-Ethylhexyl)phthalate (B2EHP)	1 / 1	5.9	NA
Inorganic Chemicals:			
* Aluminum (AL)	1 / 1	815	<10
Barium (BA)	1 / 1	15.6	74
* Cadmium (CD)	1 / 1	4.0	<1
Calcium (CA)	1 / 1	10,600	4,400 - 14,000
Chloride (CL)	1 / 1	93,000	12,000 - 46,000 (f)
* Copper (CU)	1 / 1	12.2	1
Iron (FE)	1 / 1	642	230 - 2,700 (f)
Magnesium (MG)	1 / 1	9,080	200 - 7,100
Manganese (MN)	1 / 1	24.6	100 - 700 (f)
Nitrite/Nitrate (NIT) (g)	1 / 1	960	100 - 5,300
Potassium (K)	1 / 1	3,730	1,000 - 3,000
Sodium (NA)	1 / 1	44,300	6,700 - 21,000
Sulfate (SO4)	1 / 1	17,100	7,000 - 21,000 (f)

(a) USATHAMA chemical codes listed in parentheses.
(b) The number of samples in which a chemical was detected divided by the total number of samples analyzed for that chemical.
(c) Total concentrations reported.
(d) Background concentrations from surface waters near APG. Data derived from EPA STORET database. See text. Concentrations are dissolved concentrations, except as noted.
(e) Samples: GQSW6 and GQSW8.
(f) Total concentrations reported.
(g) Concentration is reported as nitrite/nitrate non-specific. The value reported is assumed to represent the total concentration of nitrate/nitrite.
(h) Sample: GQSW3.

* = Selected as a chemical of potential concern. See text.
NA = Not available.

TABLE 9-6

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN FOR GRACES QUARTERS

			Surface Water			
	Groundwater		Northern Disposal Area		Southern Disposal Area	
Chemical (a)	Surficial Aquifer	Confined Aquifer	Gunpowder River	On-Site	Gunpowder River	On-Site
Organic Chemicals:						
Benzene (C6H6)	X					
Carbon Tetrachloride (CCL4)	X					
Chloroform (CHCL3)	X	X				
1,1-Dichloroethene (11DCE)	X					
1,2-Dichloroethene [Total] (12DCE)	X	X				
Ethyl Benzene (ETC6H5)	X					
bis(2-Ethylhexyl)phthalate (B2EHP)	X	X		X	X	X
1,1,2,2-Tetrachloroethane (TCLEA)	X	X				
Toluene (MEC6H5)	X					
Trichloroethene (TRCLE)	X	X				
Xylenes [Total] (XYLEN)	X					
Inorganic Chemicals:						
Aluminum	X		X	X	X	X
Cadmium			X		X	
Copper			X	X	X	X
Iron	X		X	X		X
Manganese	X	X				X
Nickel	X		X			
Silver	X	X				
Thallium	X					
Zinc	X					

(a) USATHAMA chemical codes listed in parentheses.

X = Selected as a chemical of potential concern.

NOTE: Blanks in this table indicate that a chemical was not selected as a chemical of potential concern either because (1) it was not detected in a given medium and/or site, or (2) it was detected at background concentrations (inorganic chemicals only). See text for this information.

potential source of petroleum contamination in this area. In addition, soil gas results (NERI 1990) indicate a potential source of petroleum contamination around the primary test area. Several inorganics in the surficial aquifer appeared to be elevated above background concentrations including aluminum, iron, manganese, nickel, silver, thallium, and zinc. In the confined aquifer, fewer inorganics (only manganese and silver) appeared to be elevated above background concentrations. Several disposal and test areas at Graces Quarters were identified as potential sources of inorganic contamination in the surficial aquifer and confined aquifer (see Section 9.2.1).

As part of the hydrogeological investigation (USGS 1990), surface water samples were collected from on-site ditches and the Gunpowder River in the northern and southern disposal areas (no surface water samples were collected from Dundee Creek or Saltpeter Creek). Surface water samples were analyzed only for volatile and semivolatile organic compounds, and total inorganics (i.e., samples were not filtered before analysis). Bis(2-ethylhexyl)phthalate was the only organic compound detected in surface water samples. Although this chemical is a common laboratory contaminant, phthalates were reportedly used at Graces Quarters as thickening agents used in chemical munitions and agents as part of tests conducted by Dougway Proving Ground from 1968 to 1972. Therefore, this chemical could be site-related. Several inorganic chemicals appeared to be elevated above background concentrations in surface water samples from Graces Quarters including aluminum, cadmium, copper, iron, manganese, and nickel. The same chemicals of concern identified in on-site surface water samples at the northern disposal area were selected as chemicals of potential concern at the southern disposal area. Aluminum and copper were selected as chemicals of concern for all surface water bodies. Copper and cadmium were selected as chemicals of potential concern in surface water but not in groundwater.

Given the disposal history of Graces Quarters, other chemicals may be present as displayed in Table 9-7. Many of these chemicals were either not sampled for in groundwater and surface water and/or the media in which they are likely to be present (i.e., soil and sediments) were not evaluated. The majority of these chemicals would tend to remain bound to soil given their chemical properties. In addition, storm runoff may result in transport of the soil particles to surface water bodies, thereby contaminating sediments. It is likely, however, that high concentrations of these chemicals in soil and sediment may result in the partitioning of a small measurable fraction in groundwater and surface water.

9.3 HUMAN HEALTH RISK ASSESSMENT

This section addresses the potential human health risks associated with the Graces Quarters study area in the absence of remedial actions. This human health risk assessment is divided into three principal sections. Section 9.3.1 evaluates and provides estimates of potential human exposures for the chemicals of concern at the site, and Section 9.3.2 summarizes relevant toxicity information for the chemicals of potential concern. Section 9.3.3 provides quantitative and qualitative estimates of human health risks.

9.3.1 EXPOSURE ASSESSMENT

This section identifies the pathways by which human populations may be exposed to chemicals of potential concern at or originating from Graces Quarters and selects pathways for further evaluation. In this evaluation, consideration was given to the mechanisms by which the chemicals of potential concern may migrate in the environment (as discussed in Section 9.2). Only complete pathways were

TABLE 9-7

CHEMICALS OF CONCERN POTENTIALLY PRESENT AT GRACES QUARTERS (a)

Group	Chemical	Comments
Lethal Chemical Agents	VX Distilled Mustard (HD) Sarin (GB) Soman (GD) Tabun (GA) EA 3990	Historical information indicates that these chemicals were tested and disposed in small quantities at Graces Quarters. Agents were reportedly decontaminated before disposal. No bulk disposal occurred at Graces Quarters. Potentially impacted media include soil, surficial groundwater and sediments. These chemicals may persist primarily in subsurface soil.
Incapacitating Agents	o-Chlorobenzylidene Malononitrile (CS) Adamsite (DM) Chloroacetophenone (CN) 3-Quiniclidinyl Benzilate (BZ)	Relatively small quantities of these chemicals were used at Graces Quarters. These chemicals are all relatively persistent in the environment and may be present in subsurface soil.
Decontaminating Agents	Calcium Hypochlorite (HTH) Supertropical Bleach (STB) Sodium Hydroxide (NaOH) DS-2 Decontamination agent - noncorrosive (DANC)	Decontamination agents were used extensively at Graces Quarters to decontaminate solid waste before disposal. HD, VX, and fuming nitric acid were decontaminated in the HD Test annuli area. Decontamination studies also were conducted in the primary test area (decontamination trench). Decontamination agents are relatively soluble and would tend to partition to groundwater and surface water.
Smoke/Incendiary Materials	Fuming Nitric Acid White Phosphorus (WP) Triethylaluminum (TEA) Sulfur Trioxide and Chlorosulfonic Acid mixture (FS)	Smoke/incendiary materials were used in the primary test area and HD annuli. These chemicals are relatively soluble and would tend to partition to surficial groundwater and surface water.
Pesticides	Telvar Dibrom 14 Malathion	Pesticides, primarily Telvar, were used to clear testing areas of vegetation. These compounds are not likely to partition to any significant degree to groundwater or soil. Rather, these chemicals would tend to persist in surface soil and subsurface soil.
Clothing Impregnating Compounds	TCPU	This chemical was not analyzed for as part of the USGS study. However, historical sampling data indicate that it is present in sediments of the area.

(a) Based on historical information. Chemicals listed are those potentially present in the greatest quantities. A large number of other chemicals could be present in smaller quantities at Graces Quarters.

selected for further evaluation. Evaluations of exposures were quantitative or qualitative depending upon several factors, including the probability of exposure, the potential magnitude of exposure, and the availability of data to support quantitative evaluations. Exposure point concentrations and daily intakes were estimated for all pathways selected for quantitative evaluation.

This exposure assessment is organized into three principal sections. Section 9.3.1.1 discusses potential exposure pathways under current land-use conditions and Section 9.3.1.2 discusses those potentially occurring under hypothetical future land-use conditions. Section 9.3.1.3 presents estimates of potential human exposures for those pathways selected for quantitative evaluation.

9.3.1.1 Potential Exposure Pathways Under Current Land-Use Conditions

Graces Quarters is an undeveloped peninsula located in the Edgewood Area of APG. It is located approximately 1/8 to 1/4 of a mile from the Gunpowder Falls State Park. The Towns of Harewood and Harewood Park are located 1 mile northwest of the site. The Baltimore city limits are approximately 4 miles west of the site. Residential development in the area surrounding Graces Quarters is very sparse. The closest well to Graces Quarters is located at the Gunpowder Falls State Park, approximately 1/4 miles west of the site and 1/2 miles west of the nearest disposal area. The closest residential well is approximately 1/2 miles southwest of the site and 1 mile from the nearest disposal area; this well is located on a peninsula across Dundee Creek from Graces Quarters.

Graces Quarters is not open to the public, with the exception of limited hunting. Hunting is limited to active and retired civilian and military personnel and their immediate families, as well as sponsored guests. Hunting stands, which are assigned using daily drawings, are located in unused areas of Graces Quarters not within testing or disposal areas identified in the USGS (1990) study. The pursuit of wounded game or dogs outside of assigned areas without permission is prohibited. In addition, fishing and crabbing are not permitted along the Graces Quarters shoreline. There is a chain-link fence that prevents access to the site by land, and warning signs are posted along the Graces Quarters shoreline to deter fisherman and others from entering the site by water.

No military activities occur at Graces Quarters. The U.S. Air Force holds a lease, but does not currently use the site. APG employees and military personnel may use portions of the site for hunting as described above.

At one time, the Federal Emergency Management Agency (FEMA) operated a radio tower located near one of the former HD test annuli along the service road. The FEMA lease has expired, and the radio tower is not used.

There are reportedly two wells (other than monitoring wells) at Graces Quarters -- a hand-dug well used by previous residents of a farm house and a well used by FEMA. Neither of these wells (which exist in the surficial aquifer) is currently used. The FEMA well (well Q20A near the FEMA tower) was sampled during the USGS investigation. This well was reportedly used in the past as a standby well. It is believed that bottled potable water was generally used as at Carroll Island in the past.

9.3.1.1.1 Potential Chronic/Subchronic Exposure Pathways Under Current Land-Use Conditions

Table 9-8 summarizes the pathways by which humans could be exposed to chemicals at or originating from Graces Quarters under current land-use conditions. Potential exposure pathways are discussed below by exposure medium.

Soil and Sediment. The only population under current land-use conditions who may potentially come into direct contact with chemicals of potential concern in surface soil and sediment are hunters in prohibited areas at Graces Quarters. Such illegal activities are expected to be infrequent and not to involve significant contact with soils.

No sampling data are currently available from the USGS (1990) study to characterize any contamination in soils or sediments at Graces Quarters. In one surface soil sample collected from the primary test area in 1977, concentrations of hydrocarbons, alkyl benzenes, phthalates, PAHs, and PCBs were detected. In addition, several sediment samples collected in the late 1970s had detected concentrations of TCPU.

Based on the expected infrequency of hunting in restricted areas and the low potential for this activity to involve contact with soils and resultant incidental ingestion and dermal absorption of chemicals of potential concern, this pathway was not evaluated in this assessment.

Since no construction or other ground-disturbing activities currently take place at Graces Quarters, no exposure will occur to subsurface soils under current land-use conditions.

Groundwater. There are no on-site potable wells in use at Graces Quarters. Therefore, no populations are exposed to chemicals of potential concern in groundwater under current land-use conditions.

As previously discussed, two off-site wells used for drinking water are located within 1/2 mile of Graces Quarters. No details of the construction or the water quality of these wells are available. Given the hydrogeology of the site and the location of these wells, however, it does not appear that contaminants from Graces Quarters would impact the groundwater quality of these wells. One of these wells is located on a neighboring peninsula, across Dundee Creek; surficial groundwater from Graces Quarters, which discharges into Dundee Creek, is therefore not hydraulically connected to groundwater on this peninsula. The deeper confined aquifers on these peninsulas may be hydraulically connected. However, because very little contamination was detected in the confined aquifer at Graces Quarters, the potential for any impact on the deeper groundwater on the neighboring peninsula is considered to be negligible.

The well located to the west of Graces Quarters is in the Gunpowder Falls State Park. This well is not in the direction of groundwater flow (to the southwest in this area) and is therefore unlikely to receive contaminants from waste disposal areas at Graces Quarters. As noted above no data are currently available to verify this or to evaluate this pathway. Therefore no groundwater pathways were evaluated under current land-use conditions.

Surface Water. Hunters who hunt game outside of specified hunting areas at Graces Quarters are the only population who might have contact with surface water, such as on-site ditches. It is suspected that such illegal hunting is infrequent, and the potential for dermal contact with surface water during hunting activities would be insignificant in any case. This pathway was therefore not evaluated in this assessment.

TABLE 9-8

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT GRACES QUARTERS

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Surface Soil-Sediment/ - Graces Quarters Disposal Area - Graces Quarters Dump - Primary Test Area - Secondary Test Area - HD Test Annuli - Bunker - Northern Dump - Southern Dump - Service Area	Dermal contact and/or incidental ingestion by hunters.	Negligible due to hunting access restrictions and low potential to contact unvegetated soils during hunting.	No soil or sediment data available.	None, due to low potential for exposure and lack of data.
Groundwater/ On-site	No current use of water from two existing on-site wells.	No potential for exposure. Pathway not complete.	NA. Pathway not complete.	None. No complete pathway exists.
Groundwater/ Off-site	Ingestion, dermal contact and inhalation by users of well on neighboring peninsula to southwest.	No data available for this well. Potential for contamination from Graces Quarters is negligible, since land masses separated by Dundee Creek into which surficial groundwater dishcarges and minimal contamination in confined aquifer which may be connected under Dundee Creek.	Poor. No data available for this well at this time.	None, due to low potential for exposure and lack of data.
	Ingestion, dermal contact and inhalation by users of well at Gunpowder Falls State Park.	No data available for this well. Well is located 0.5 miles sidegradient from nearest disposal area on Graces Quarters and is therefore considered unlikely to receive site contamination.	Poor. No data available for this well at this time.	None, due to low potential for exposure and lack of data.
Surface Water/ - Northern Disposal Area: On-Site Ditches - Northern Disposal Area: Gunpowder River - Southern Disposal Area: On-Site Ditches - Southern Disposal Area: Gunpowder River	Dermal contact by hunters.	Negligible, due to hunting access restrictions, low potential for contact during hunting, and low levels of chemicals of concern which could be absorbed dermally.	Limited surface water monitoring data available.	None, due to low potential for significant exposure.

See footnotes on the following page.

TABLE 9-8 (continued)

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER CURRENT LAND-USE CONDITIONS AT GRACES QUARTERS

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential for Significant Exposure (a)	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Air/ - Graces Quarters Disposal Area - Graces Quarters Dump - Primary Test Area - Secondary Test Area - HD Test Annuli - Bunker - Northern Dump - Southern Dump - Service Area	Inhalation of vapors from surface soil/sediments and dust from surface soil by hunters.	Negligible, due to hunting access restrictions and likely low air concentrations of volatiles and low potential for dust from the mainly vegetated site.	No air or soil data available.	None, due to low potential for exposure and lack of data.
Fish and Crab/ - Northern Disposal Area: Gunpowder River - Southern Disposal Area: Gunpowder River	Ingestion of contaminated fish/crab by fishermen violating the fishing restriction along the shores of Graces Quarters.	Moderate. Fishing is known to occur (although illegally) and chemicals detected in surface water (bis(2-ethylhexyl) phthalate) and in sediment (TCPU) may bioaccumulate in tissue.	Poor. Limited surface water data and no recent, validated sediment data available at this time.	Qualitative.
Upland Game/Early Migratory Birds	Ingestion of contaminated upland game/early migratory birds by hunters.	Negligible. Migratory birds should spend a small fraction of feeding time at disposal areas, and the probability is low that a hunter would consume significant quantities of contaminated game.	Poor. Limited surface water data and no recent, validated sediment or soil data available at this time.	None, due to low potential for exposure and lack of data.
Soil/Air Ordnance, Unexploded	Acute Hazards: Illegal hunters encountered unexploded ordnances with subsequent explosion resulting in dermal and inhalation exposures.	Negligible. Hunting is not permitted in areas of concern and testing activities that could have results in unexploded ordinace were limited at this site.	Poor. Magnetometer surveys conducted only within and around most disposal areas. No unexploded ordnances were found in these areas.	None due to low potential for exposure and lack of data.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.

NA = Not applicable.

Air. Exposure to chemicals of potential concern in air may occur from inhalation. Chemicals that tend to bind tightly to soil particles (e.g., semivolatile chemicals and inorganic chemicals) may be inhaled as airborne dust particles. Other chemicals such as chlorinated aliphatic compounds and many chemical agents (e.g., VX and mustard gas) may be released via volatilization from surface and subsurface soils, wastes, and groundwater or surface water to air.

No air or soil monitoring data were available for Graces Quarters. A soil gas survey conducted by NERI (1990) did indicate the presence of several plumes of volatile organic compounds (VOCs) in groundwater. These chemicals may migrate to the surface and be released to the air. It is suspected, however, that the current extent of volatilization is negligible, given the relatively low levels of volatiles detected in groundwater and the small likelihood that volatile chemicals were disposed in bulk and are present in the subsurface. In addition, any release of VOCs or contaminated dust particles to the air would be thoroughly diluted in the atmosphere. Therefore, the magnitude of exposure to any hunters who trespass onto restricted areas is considered negligible (particularly given the low frequency and duration of possible exposure). The potential exposure to hunters and APG employees who visit Graces Quarters and inhale air in the vicinity of the disposal and test areas was not evaluated in this assessment.

Biota. Individuals who consume fish or crabs obtained along the Graces Quarters shoreline (particularly along the southern disposal area shoreline) may be exposed to chemicals that can bioaccumulate in fish/crab tissue (e.g., bis[2-ethylhexyl]phthalate and TCPU which were detected in surface water). Violations of the fishing restriction have been observed, but the frequency of these violations is not known. The potential impact on people who ingest fish caught along the Graces Quarters shoreline was not assessed quantitatively given the lack of exposure frequency information and limited surface water and sediment data. This pathway was evaluated qualitatively.

Individuals hunting at Graces Quarters may potentially be exposed to chemicals from Graces Quarters through ingestion of contaminated upland game or early migratory birds. The potential for this type of exposure to occur is considered to be negligible, however, because migratory birds are likely to spend only a very small fraction of their feeding time (if any) at disposal areas and because hunters are not likely to consume significant quantities of contaminated game.

9.3.1.1.2 Potential Acute Hazards Under Current Land-Use Conditions

As discussed in Section 9.1, Graces Quarters was used to test various munitions and chemical agents from the mid-1940s to the early 1970s. The extent of testing at Graces Quarters was less than at other APG sites. The majority of the testing took place at the primary test area. Magnetometer surveys were conducted only at the disposal areas at Graces Quarters primarily to identify buried metal drums. No unexploded ordnance were found at the disposal area as a result of the survey. No surveys were conducted at other areas of concern at Graces Quarters (e.g., the primary test area). Notwithstanding these data gaps, the potential for acute hazards to individuals illegally hunting in restricted areas at Graces Quarters is considered likely to be low given that lethal compounds were decontaminated before disposal and the low level of testing that took place at Graces Quarters. This pathway therefore was not evaluated.

In summary, no current land-use exposure pathways were quantitatively evaluated for Graces Quarters. Exposure of individuals who consume fish caught along the Graces Quarters' shoreline, in violation of the current fishing restriction, was assessed qualitatively.

9.3.1.2 Potential Exposure Pathways Under Future Land-Use Conditions

It is highly unlikely that Graces Quarters would be used for future residential development, and there are no plans to lift the current restrictions on access to the area. With respect to future military use, the U.S. Air Force, the current leasee of Graces Quarters, plans to construct a radio receiving station at the site. No additional exposure pathways were identified with respect to future land-use of the site with the exception of the possible use of groundwater. These additional exposure pathways are described below and summarized in Table 9-9.

9.3.1.2.1 Potential Chronic/Subchronic Exposure Pathways Under Future Land-Use Conditions

Groundwater at Graces Quarters is considered to be Class IIB groundwater under the EPA Groundwater Protection Strategy (EPA 1986a). Class IIB groundwater (groundwater containing less than 10,000 mg/L total dissolved solids and able to yield 150 gallons per day) is considered to be a potential source of drinking water. Because of this classification and the fact that there is a supply well (currently closed) on Graces Quarters, it is conceivable that groundwater could be used in the future. Therefore, future land-use scenarios involving ingestion of groundwater from the surficial aquifer and confined aquifer were quantitatively evaluated. In addition, future ingestion of groundwater from the currently closed supply well (Q20A, located along the service road) were quantitatively evaluated.

The U.S. Air Force, which currently holds a lease on Graces Quarters, plans to construct a radio receiving station at the site. The project is reported to be "on hold"; no additional details are available. In the event that this construction takes place, construction workers in disposal and testing areas could be exposed via direct contact with surface and subsurface soils and inhalation of volatile organic chemicals. As previously discussed, no surface or subsurface soil monitoring data are available with which to evaluate the potential impact to construction workers. Therefore, this pathway was qualitatively evaluated in this assessment.

9.3.1.2.2 Potential Acute Hazards Under Future Land-Use Conditions

Graces Quarters was used to test various munitions and chemical agents from the mid-1940s to the early 1970s. Future construction activities at the site may significantly increase the potential for acute hazards given that subsurface soil would be disturbed. Unexploded ordnance and "hot spots" of various chemicals (including agents) that might be present in subsurface soil could present acute hazards to construction workers through dermal and/or inhalation exposure. Because a magnetometer study is required before any excavation however, the disturbance of unexploded ordinance as a result of excavation is unlikely to occur. Additionally, as noted above under the discussion of acute hazards under current land use, the potential for acute hazards to occur at Graces Quarters is not as high as in many other areas of APG, because of the type of wastes disposed of and the activities that took place there. There are insufficient data to quantitatively evaluate this pathway, given the lack of soil monitoring data, and information on disposal and testing. However, this pathway involving acute hazards to future construction workers was qualitatively evaluated together with the pathway involving chronic exposure from this activity as discussed above in Section 9.3.1.2.1.

TABLE 9-9

POTENTIAL PATHWAYS OF HUMAN EXPOSURE UNDER FUTURE LAND-USE CONDITIONS AT GRACES QUARTERS

Exposure Medium/ Source Area	Potential Exposure Pathway	Potential For Significant Exposure	Adequacy of Data to Evaluate Pathway	Method of Evaluation
Groundwater (Surficial Aquifer)	Ingestion, dermal contact and inhalation by future workers.	Moderate. Although future workers are unlikely to use the surficial aquifer as a water supply, significant concentrations of chemicals are present in the surficial aquifer.	Good. Data sufficient.	Ingestion: Quantitative Dermal and Inhalation: Qualitative
Groundwater (Confined Aquifer)	Ingestion, dermal contact and inhalation by future workers.	Low. Future workers are unlikely to use groundwater from the confined aquifer, and low concentrations of chemicals of concern were detected.	Good. Data sufficient.	Ingestion: Quantitative Dermal and Inhalation: Qualitative
Groundwater (Service Road Well)	Ingestion, dermal contact and inhalation by future workers.	Low. Use of this well as a source of drinking water is unlikely and only 2 chemicals of concern are present, both at low concentrations.	Good. Data sufficient.	Ingestion: Quantitative Dermal and Inhalation: Qualitative
Surface and Subsurface Soil	Direct contact and/or incidental ingestion by future construction workers.	Unknown. Future use is planned but location is not known. Soil sample analyses are not available.	Poor. No recently collected, validated soil data available and building plans unknown.	Qualitative.
Air	Inhalation of vapors from surface and subsurface soils by future construction workers.	Unknown. Future use is planned but location is not known. Soil gas results indicate several plumes of VOC soil gas exist below the ground surface.	Poor. No recently collected, validated soil data available, soil gas results cannot be used quantitatively, and building plans unknown.	Qualitative.
Soil/Air	Acute hazards: fire or explosion at Graces Quarters with subsequent dermal and inhalation exposures to future site workers.	Moderate. Unexploded ordnance are not likely to be encountered; however, exposures could be substantial.	Poor. Magnetometer surveys conducted only within and around most disposal areas. No unexploded ordnance were found in these areas.	Qualitative.

ALL OTHER EXPOSURE PATHWAYS EVALUATED FOR CURRENT LAND-USE CONDITIONS (SEE TABLE 9-8) APPLY FOR FUTURE LAND USE CONDITIONS, AS WELL.

(a) Based on considerations of the types and concentrations of chemicals present, or expected to be present, and on considerations of land use.

NA = Not applicable.

9.3.1.3 Quantification of Exposure

Based on the discussion above, the following human exposure pathways were evaluated in this risk assessment.

Current Land-Use Conditions

- No current land-use exposure pathways were quantitatively evaluated. Potential exposure of individuals who ingest fish caught from the shores of Graces Quarters were qualitatively evaluated in this report.

Future Land-Use Conditions

- Exposure of hypothetical future on-site workers who may ingest surficial and confined aquifer groundwater from Graces Quarters.
- Exposure of hypothetical future on-site workers who may ingest groundwater from the existing supply well (Q20A) located on the service road.
- Potential chronic exposure of future on-site construction workers who (1) may be exposed to chemicals of potential concern via direct contact with soils and inhalation of dust and vapors, and (2) may encounter acute hazards (qualitative evaluation only).

To assess exposure quantitatively, the chronic daily intake (CDI) of each chemical of potential concern was estimated for the reasonable maximum exposure (RME) case (EPA 1989), as described in Chapter 4. The assumptions used in evaluating exposure to hypothetical future on-site workers via ingestion of groundwater presented in Table 9-10 were based on EPA (1989) where possible. In other instances, best professional judgment and site-specific information were used. For the RME case, hypothetical on-site workers were assumed to ingest 1 liter of groundwater per day for a maximum of 241 days per year (assuming a 5-day work week, 9 holidays, and 10 vacation days) over a 20-year period. Workers were assumed to weigh an average of 70 kg over a lifetime.

The methodology for estimating exposure point concentrations for the RME case is summarized in Chapter 4. Exposure point concentrations used to estimate CDIs for ingestion of surficial and confined groundwater by a hypothetical future on-site worker are shown in Tables 9-11 and 9-12, respectively. The data used to estimate exposure point concentrations for this assessment are summarized in Tables 9-2 (surficial aquifer) and 9-3 (confined aquifer). Monitoring results from USATHAMA well Q20A were also used to estimate CDIs from ingestion of surficial groundwater from this well (Q20A was used in the past as a non-potable source of water at the FEMA transmitter station). Bis(2-ethylhexyl)phthalate and silver were the only two chemicals of potential concern present in this well. The maximum detected concentration of bis(2-ethylhexyl)phthalate of 8.7 μg/L was detected at Q20A. In addition, silver was detected only at well Q20A at a concentration of 5 μg/L.

CDIs were calculated using the exposure parameters, exposure point concentrations, and the equation presented below:

$$CDI = \frac{(C_w)(WI)(E)(YR)}{(BW)(DY)(YL)} \qquad \text{(Eq. 1)}$$

TABLE 9-10

PARAMETERS USED TO ESTIMATE WORKER EXPOSURES TO GROUNDWATER AT GRACES QUATERS UNDER FUTURE LAND-USE CONDITIONS

Parameter	Value
Ingestion Rate (a)	1 L/day
Exposure Duration (b)	20 years
Exposure Frequency (c)	241 days/year
Body Weight (d)	70 kg

(a) A worker spends approximately one-half of his waking hours at work. Therefore, the worker ingestion rate was calculated by taking half of the daily water consumption rate (i.e., 0.5 x 2 L/day = 1 L/day).
(b) Based on the time a typical civilian worker spends working at APG.
(c) Assumes a typical worker works 5 days each week, takes 2 weeks vacation, and is off 9 Federal holidays each year.
(d) EPA (1989).

TABLE 9-11

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT GRACES QUARTERS SURFICIAL AQUIFER

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithimetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Benzene (C6H6)	0.3	0.3	0.9	0.3
Carbon Tetrachloride (CCL4)	240	650 (d)	5,710	650
Chloroform (CHCL3)	5.1	12 (d)	103	12
1,1-Dichloroethene (11DCE)	0.3	0.3	0.6	0.3
1,2-Dichloroethene [Total] (12DCE)	0.4	0.4	3.4	0.4
Ethyl Benzene (ETC6H5)	0.4	0.4	3.2	0.4
bis(2-Ethylhexyl)phthalate (B2EHP)	4.1	7.1	8.7	7.1
1,1,2,2-Tetrachloroethane (TCLEA)	76	200 (d)	1,940	200
Toluene (MEC6H5)	0.8	1.7 (d)	12.7	1.7
Trichloroethene (TRCLE)	40	110 (d)	952	110
Xylenes [Total] (XYLEN)	1.1	2.3 (d)	17	2.3
Inorganic Chemicals:				
Aluminum (AL)	250	350	2,110	350
Iron (FE)	1,600	9,300	21,900	9,300
Manganese (MN)	170	410	861	410
Nickel (NI)	34	39	272	39
Silver (AG)	2.4	2.5	5.0	2.5
Thallium (TL)	44	47	111	47
Zinc (ZN)	47	74	344	74

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution, except as noted.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.
(d) Value reflects a normal distribution.

TABLE 9-12

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT GRACES QUARTERS CONFINED AQUIFER

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithimetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
Organic Chemicals:				
Chloroform (CHCL3)	0.5	2.6	1.5	1.5
1,2-Dichloroethene (total) (12DCE)	0.4	1.6	1.2	1.2
bis(2-Ethylhexyl)phthalate (B2EHP)	3.0	7.9	4.2	4.2
1,1,2,2-Tetrachloroethane (TCLEA)	0.8	16	3.2	3.2
Trichloroethene (TRCLE)	0.3	0.3	0.4	0.3
Inorganic Chemicals:				
Manganese (MN)	130	6,500	276	276
Silver (AG)	2.5	2.8	3.1	2.8

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

where

CDI = chronic daily intake (mg/kg-day);

C_w = chemical concentration in water (mg/L);

WI = amount of water ingested (L/day);

E = number of exposure days (days/year);

YR = duration of exposure (years);

BW = average body weight (kg);

DY = days/year (365 days/year); and

YL = period over which risk is being estimated (i.e., a lifetime of 70 years for carcinogens, or the duration of exposure (YR) for noncarcinogens) (years).

CDIs estimated for ingestion of groundwater from the surficial and confined aquifers by hypothetical workers are presented in Tables 9-13 and 9-14. The CDIs estimated for ingestion of groundwater from USATHAMA well Q20A are presented in Table 9-15.

9.3.2 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria have been described in Chapter 4 to provide the analytical framework for the characterization of human health impacts. The health effects criteria that were used to derive estimates of risk for workers who may ingest groundwater under future land-use conditions are presented in Table 9-16. No oral toxicity criteria were available for aluminum and iron. Therefore, potential risks associated with exposure to these chemicals were not quantitatively evaluated. However, the potential contribution of these chemicals to the overall estimates of risk for the pathway involving the ingestion of groundwater by workers is discussed qualitatively in the risk characterization section. Toxicity summaries for all chemicals of potential concern for the ingestion pathway as well as the toxicological basis of the health effects criteria presented in Table 9-16 are provided in Appendix B.

9.3.3 RISK CHARACTERIZATION

In this section, the human health risks associated with Graces Quarters are discussed. The methodology used to characterize human health risks was presented in Section 4.2.3. Potential risks under current land-use conditions are presented in Section 9.3.3.1, and those under hypothetical future land-use conditions are presented in Section 9.3.3.2. Risks under current land-use conditions were evaluated qualitatively, and those under hypothetical future land-use conditions were evaluated qualitatively and quantitatively.

TABLE 9-13

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE GRACES QUARTERS SURFICIAL AQUIFER (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
Benzene (C6H6)	0.3	8.1E-07
Carbon Tetrachloride (CCL4)	650	1.8E-03
Chloroform (CHCL3)	12	3.2E-05
1,1-Dichloroethene (11DCE)	0.3	8.1E-07
bis(2-Ethylhexyl)phthlate (B2EHP)	7.1	1.9E-05
1,1,2,2-Tetrachloroethane (TCLEA)	200	5.4E-04
Trichloroethene (TRCLE)	110	3.0E-04
Chemicals Exhibiting Noncarcinogenic Effects		
Carbon Tetrachloride (CCL4)	650	6.1E-03
Chloroform (CHCL3)	12	1.1E-04
1,1-Dichloroethene (11DCE)	0.3	2.8E-06
1,2-Dichloroethene [Total] (12DCE)	0.4	3.8E-06
Ethyl Benzene (ETC6H5)	0.4	3.8E-06
bis(2-Ethylhexyl)phthlate (B2EHP)	7.1	6.7E-05
1,1,2,2-Tetrachloroethane (TCLEA)	200	1.9E-03
Toluene (MEC6H5)	1.7	1.6E-05
Trichloroethene (TRCLE)	110	1.0E-03
Xylenes [Total] (XYLEN)	2.3	2.2E-05
Manganese (MN)	410	3.9E-03
Nickel (NI)	39	3.7E-04
Silver (AG)	2.5	2.4E-05
Thallium (TL)	47	4.4E-04
Zinc (ZN)	74	7.0E-04

(a) CDIs have been calculated only for those chemicals of potential concern with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.
(b) USATHAMA chemical codes listed in parentheses.
(c) See Table 9-10 for exposure assumptions.

TABLE 9-14

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTEHTICAL FUTURE INGESTION OF GROUNDWATER AT THE GRACES QUARTERS CONFINED AQUIFER

Chemical (a)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)
Chemicals Exhibiting Carcinogenic Effects		
Chloroform (CHCL3)	1.5	4.0E-06
bis(2-Ethylhexyl)phthlate (B2EHP)	4.2	1.1E-05
1,1,2,2-Tetrachloroethane (TCLEA)	3.2	8.6E-06
Trichloroethene (TRCLE)	0.3	8.1E-07
Chemicals Exhibiting Noncarcinogenic Effects		
Chloroform (CHCL3)	1.5	1.4E-05
bis(2-Ethylhexyl)phthlate (B2EHP)	4.2	4.0E-05
1,2-Dichloroethene (total) (12DCE)	1.2	1.1E-05
1,1,2,2-Tetrachloroethane (TCLEA)	3.2	3.0E-05
Trichloroethene (TRCLE)	0.3	2.8E-06
Manganese (MN)	276	2.6E-03
Silver (AG)	2.8	2.6E-05

(a) USATHAMA chemical codes listed in parentheses.
(b) See Table 9-10 for exposure assumptions.

TABLE 9-15

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT GRACES QUARTERS USATHAMA WELL (a)

Chemical (b)	RME Concentration (ug/L)	Estimated Chronic Daily Intake (CDI) (mg/kg-day) (c)
Chemicals Exhibiting Carcinogenic Effects		
bis(2-Ethylhexyl)phthlate (B2EHP)	8.7	2.3E-05
Chemicals Exhibiting Noncarcinogenic Effects		
bis(2-Ethylhexyl)phthlate (B2EHP)	8.7	8.2E-05
Silver (AG)	5.0	4.7E-05

(a) The USATHAMA well Q20A is located along the service road and is currently closed.
(b) USATHAMA chemical codes listed in parentheses.
(c) See Table 9-10 for exposure assumptions.

TABLE 9-16

ORAL CRITICAL TOXICITY VALUES FOR CHEMICALS OF POTENTIAL CONCERN AT GRACES QUARTERS

Chemical	Chronic Reference Dose (mg/kg/day)	Uncertainty Factor (a)	Target Organ (b)	Reference Dose Source	Cancer Slope Factor (mg/kg/day)-1	EPA Weight of Evidence Classification (c)	Slope Factor Source
Organic Chemicals:							
Benzene	--	--	--	IRIS	2.90E-02	A	IRIS
Carbon Tetrachloride	7.00E-04	1,000	Liver	IRIS	1.30E-01	B2	IRIS
Chloroform	1.00E-02	1,000	Liver	IRIS	6.10E-03	B2	IRIS
1,1-Dichloroethene	9.00E-03	1,000	Liver	IRIS	6.00E-01	C	IRIS
cis-1,2-Dichloroethene	1.00E-02	3,000	Blood	HEAST	--	--	--
trans-1,2-Dichloroethene	2.00E-02	1,000	Blood	IRIS	--	--	--
Ethyl Benzene	1.00E-01	1,000	Liver/Kidney	IRIS	--	D	IRIS
bis(2-Ethylhexyl)phthalate	2.00E-02	1,000	Liver	IRIS	1.40E-02	B2	IRIS
1,1,2,2-Tetrachloroethane	4.60E-04	1,000	Liver/White Blood Cells	(d)	2.00E-01	C	IRIS
Toluene	2.00E-01	1,000	Liver/Kidney	IRIS	--	D	IRIS
Trichloroethene	7.35E-03	1,000	Liver	HA	1.10E-02	B2	HEAST
Xylenes [Total]	2.00E+00	100	Nervous System/ Mortality	IRIS	--	D	IRIS
Inorganic Chemicals:							
Aluminum	--	--	--	--	--	--	--
Iron	--	--	--	HEAST	--	--	--
Manganese	1.00E-01	1	CNS	IRIS	--	--	--
Nickel	2.00E-02	300	Body weight	IRIS	--	--	IRIS
Silver	3.00E-03	2	Skin (Argyria)	IRIS	--	D	IRIS
Thallium	7.00E-05	3,000	Blood/Hair	HEAST	--	--	HEAST
Zinc	2.00E-01	10	Blood (Anemia)	HEAST	--	--	HEAST

(a) Safety factors are the products of uncertainty factors and modifying factors. Uncertainty factors used to develop reference doses generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include the following:
- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less than chronic NOAELs to chronic NOAELs; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(b) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or system known to be affected by the chemical is listed.

(c) EPA Weight of Evidence for Carcinogenic Effects:
[A] = Human carcinogen based on adequate evidence from human studies;
[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies;
[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies; and
[D] = Not classified as to human carcinogenicity.

(d) Interim RfD approved by ECAO, Cincinnati.

NOTE: IRIS = Integrated Risk Information System - December 1, 1990.
HA = Health Advisory.
HEAST = Health Effects Assessment Summary Tables - July 1, 1990.
-- = No information available.

9.3.3.1 Potential Risks Under Current Land-Use Conditions

As discussed in Section 9.3.1.1, no current land-use exposure pathways were quantitatively evaluated in this assessment. Potential risks to individuals who ingest fish caught from the shores of Graces Quarters were qualitatively evaluated in this report. Of the chemicals detected in surface water and historical sediment data, bis(2-ethylhexyl)phthalate and TCPU have the potential to bioaccumulate in fish based on their physicochemical properties. Bis(2-ethylhexyl)phthalate was detected in surface water from the Gunpowder River along the shore of the southern disposal area at a maximum concentration of 5 µg/L. A bioaccumulation factor of 114 was reported for bis(2-ethylhexyl)phthalate in bluegill (Barrows et al. 1980 in EPA 1987). Thus, the concentrations of bis(2-ethylhexyl)phthalate in fish tissue may be approximately 100 times the concentration found in surface water. Given the toxicity of this phthalate, ingestion of fish contaminated with bis(2-ethylhexyl)phthalate from the Graces Quarters shoreline could pose a potential carcinogenic and noncarcinogenic risk. However, the extent of bis(2-ethylhexyl)phthalate contamination in the Gunpowder River is unknown. If contamination is limited to the Graces Quarters shoreline, significant accumulation in sport and commercial fish of the area is unlikely. TCPU was detected in several historical sediment samples, but the potential bioaccumulation and toxicity of TCPU and the extent of contamination are unknown.

9.3.3.2 Potential Risks Under Future Land-Use Conditions

As discussed in Section 9.3.1.3, the following future land-use exposure pathways were evaluated:

- Exposure of hypothetical future on-site workers who may ingest surficial and confined aquifer groundwater from Graces Quarters;
- Exposure of hypothetical future on-site workers who may ingest groundwater from the existing USATHAMA well located on the service road; and
- Potential chronic or acute exposure of future on-site construction workers who may be exposed to chemicals of potential concern via direct contact with soils and inhalation of dust and VOCs.

Several data gaps exist that may significantly impact the quantitative characterization of risk from use of groundwater at Graces Quarters. Groundwater samples were analyzed only for volatile and semivolatile chemicals and inorganics. Given the disposal history of Graces Quarters, other chemicals of concern may be present in groundwater (e.g., VX, sarin, soman, EA 3990, CS-1, and mustard). The potential contribution of risk associated with these chemicals could not be included in this assessment (see Section 9.6 for further discussion).

9.3.3.2.1 Potential Risks to Hypothetical Future On-Site Workers from Use of Surficial Aquifer Groundwater

Estimated carcinogenic and noncarcinogenic risks to hypothetical future on-site workers from ingestion of groundwater from the surficial aquifer are presented in Table 9-17. The total excess cancer risk from ingestion of groundwater from the surficial aquifer for the RME case is $3x10^{-4}$. Chemical-specific cancer risks associated with ingestion for the RME case ranged from $2x10^{-8}$ to $2x10^{-4}$. Most of the carcinogenic risk was associated with exposure to carbon tetrachloride and 1,1,2,2-tetrachloroethane. The maximum concentrations for these chemicals were detected in monitoring well Q14A, which is located in the center of the primary test area.

TABLE 9-17

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE GRACES QUARTERS SURFICIAL AQUIFER (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
Benzene (C6H6)	8.1E-07	2.9E-02	A	2E-08
Carbon Tetrachloride (CCL4)	1.8E-03	1.3E-01	B2	2E-04
Chloroform (CHCL3)	3.2E-05	6.1E-03	B2	2E-07
1,1-Dichloroethene (11DCE)	8.1E-07	6.0E-01	C	5E-07
bis(2-Ethylhexyl)phthlate (B2EHP)	1.9E-05	1.4E-02	B2	3E-07
1,1,2,2-Tetrachloroethane (TCLEA)	5.4E-04	2.0E-01	C	1E-04
Trichloroethene (TRCLE)	3.0E-04	1.1E-02	B2	3E-06

TOTAL	--	--	--	3E-04

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
Carbon Tetrachloride (CCL4)	6.1E-03	7.0E-04	1,000	Liver	9E+00
Chloroform (CHCL3)	1.1E-04	1.0E-02	1,000	Liver	1E-02
1,1-Dichloroethene (11DCE)	2.8E-06	9.0E-03	1,000	Liver	3E-04
1,2-Dichloroethene [Total] (12DCE)	3.8E-06	1.0E-02 (f)	3,000	Blood	4E-04
Ethyl Benzene (ETC6H5)	3.8E-06	1.0E-01	1,000	Liver/Kidney	4E-05
bis(2-Ethylhexyl)phthlate (B2EHP)	6.7E-05	2.0E-02	1,000	Liver	3E-03
1,1,2,2-Tetrachloroethane (TCLEA)	1.9E-03	4.6E-04	1,000	Liver/WBC	4E+00
Toluene (MEC6H5)	1.6E-05	2.0E-01	1,000	Liver/Kidney	8E-05
Trichloroethene (TRCLE)	1.0E-03	7.35E-03	1,000	Liver	1E-01
Xylenes [Total] (XYLEN)	2.2E-05	2.0E+00	100	Nerv Sys/Mortality	1E-05
Manganese (MN)	3.9E-03	1.0E-01	1	CNS	4E-02
Nickel (NI)	3.7E-04	2.0E-02	300	Body weight	2E-02
Silver (AG)	2.4E-05	3.0E-03	2	Skin (Argyria)	8E-03
Thallium (TL)	4.4E-04	7.0E-05	3,000	Blood/Hair	6E+00
Zinc (ZN)	7.0E-04	2.0E-01	10	Blood (Anemia)	3E-03

HAZARD INDEX	--	--	--	--	> 1 (2E+01)

(a) Risks are calculated only for chemicals with toxicity criteria. The following chemicals of potential concern are not presented due to lack of toxicity criteria: aluminum and iron.
(b) USATHAMA chemical codes listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects:
    [A] = Human carcinogen based on adequate evidence from human studies;
    [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and
    [C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.
(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.
(f) The RfD for cis-1,2-dichloroethene is used in the absence of an RfD for total 1,2-dichloroethene.

For noncarcinogenic risks, the Hazard Index associated with ingestion of groundwater from the surficial aquifer for the RME case was above 1 (20). Therefore, noncarcinogenic effects associated with ingestion of groundwater from the surficial aquifer may occur. The chemical specific CDI:RfD ratios for the majority of the chemicals were well below 1, with the exceptions of carbon tetrachloride (CDI:RfD = 9), thallium (CDI:RfD = 6), and 1,1,2,2-tetrachloroethane (CDI:RfD = 4). Monitoring well Q15, the only monitoring well with a detected concentration of thallium, is located downgradient of the decontamination trench in the vicinity of the primary test area. As mentioned above, the maximum concentration of 1,1,2,2-tetrachloroethane was detected in monitoring well Q14A, which is located in the center of the primary test area. As shown in Table 9-17, thallium and 1,1,2,2-tetrachloroethane have different endpoints of toxicity. The liver is the target organ for both carbon tetrachloride and 1,1,2,2-tetrachloroethane.

The above risks were estimated for ingestion of water only. Volatile chemicals present in surficial groundwater (particularly carbon tetrachloride and 1,1,2,2-tetrachloroethane detected at the primary test area) may pose significant health risks if groundwater is used for showering or production uses that result in volatilization. Inhalation of these volatilized chemicals may result in exposures and risks on the same order of magnitude as those estimated for the groundwater ingestion pathway.

9.3.3.2.2 Potential Risks to Hypothetical Future On-Site Workers from Use of Confined Aquifer Groundwater

Estimated carcinogenic and noncarcinogenic risks to hypothetical future on-site workers from ingestion of groundwater from the confined aquifer are present in Table 9-18. The total excess cancer risk from ingestion of groundwater from the confined aquifer for the RME case is $2x10^{-6}$. Chemical-specific cancer risks associated with ingestion for the RME case ranged from $9x10^{-9}$ to $2x10^{-6}$. The majority of carcinogenic risk was associated with exposure to 1,1,2,2-tetrachloroethane. 1,1,2,2-Tetrachloroethane was detected only in monitoring well Q16A, which is located downgradient of the primary test area. The potential carcinogenic risks associated with using groundwater from the confined aquifer were approximately 100 times lower than the potential carcinogenic risks associated with using groundwater from the surficial aquifer. Only four suspected carcinogenic chemicals were detected in the confined aquifer, each with concentrations below 5 μg/L.

For noncarcinogenic risks, the Hazard Index associated with ingestion of groundwater from the confined aquifer for the RME case was below a value of 1 (0.1). Therefore, noncarcinogenic effects associated with ingestion of groundwater from the confined aquifer are not expected.

As discussed in the previous section, inhalation of volatilized chemicals may result in exposures and risks on the same order of magnitude as those estimated for the groundwater ingestion pathway. Therefore, exposure via this pathway would not result in significant risks, given the low risks estimated for the ingestion pathway.

9.3.3.2.3 Potential Risks to Hypothetical Future On-Site Workers from Use of USATHAMA Well Q20A

Estimated carcinogenic and noncarcinogenic risks to hypothetical future on-site workers from ingestion of groundwater from USATHAMA well Q20A are presented in Table 9-19. Bis(2-ethylhexyl) phthalate and silver were the only chemicals of potential concern identified in the groundwater sample collected from this well. The potential excess cancer risks from ingestion of bis(2-ethylhexyl)phthalate in groundwater from this well for the RME case is $3x10^{-7}$, which is below the EPA target risk level for

TABLE 9-18

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE GRACES QUARTERS CONFINED AQUIFER

Chemicals Exhibiting Carcinogenic Effects (a)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (b)	Upper Bound Excess Lifetime Cancer Risk
Chloroform (CHCL3)	4.0E-06	6.1E-03	B2	2E-08
bis(2-Ethylhexyl)phthlate (B2EHP)	1.1E-05	1.4E-02	B2	2E-07
1,1,2,2-Tetrachloroethane (TCLEA)	8.6E-06	2.0E-01	C	2E-06
Trichloroethene (TRCLE)	8.1E-07	1.1E-02	B2	9E-09
TOTAL	--	--	--	2E-06

Chemicals Exhibiting Noncarcinogenic Effects (a)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (c)	Target Organ (d)	CDI:RfD Ratio
Chloroform (CHCL3)	1.4E-05	1.0E-02	1,000	Liver	1E-03
bis(2-Ethylhexyl)phthlate (B2EHP)	4.0E-05	2.0E-02	1,000	Liver	2E-03
1,2-Dichloroethene [Total] (12DCE)	1.1E-05	1.0E-02 (e)	3,000	Blood	1E-03
1,1,2,2-Tetrachloroethane (TCLEA)	3.0E-05	4.6E-04	1,000	Liver/WBC	7E-02
Trichloroethene (TRCLE)	2.8E-06	7.35E-03	1,000	Liver	4E-04
Manganese (MN)	2.6E-03	1.0E-01	1	CNS	3E-02
Silver (AG)	2.6E-05	3.0E-03	2	Skin (Argyria)	9E-03
HAZARD INDEX	--	--	--	--	< 1 (1E-01)

(a) USATHAMA chemical codes listed in parentheses.

(b) EPA Weight of Evidence for Carcinogenic Effects:

[B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies; and

[C] = Possible human carcinogen based on limited evidence from animal studies in the absence of human studies.

(c) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.

(d) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

(e) The RfD for cis-1,2-dichloroethene is used in the absence of an RfD for total 1,2-dichloroethene.

TABLE 9-19

POTENTIAL RISKS ASSOCIATED WITH HYPOTHETICAL FUTURE INGESTION OF GROUNDWATER AT THE GRACES QUARTERS USATHAMA WELL (a)

Chemicals Exhibiting Carcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Slope Factor (mg/kg-day)-1	Weight of Evidence Class (c)	Upper Bound Excess Lifetime Cancer Risk
bis(2-Ethylhexyl)phthlate (B2EHP)	2.3E-05	1.4E-02	B2	3E-07

Chemicals Exhibiting Noncarcinogenic Effects (b)	Estimated Chronic Daily Intake (CDI) (mg/kg-day)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (d)	Target Organ (e)	CDI:RfD Ratio
bis(2-Ethylhexyl)phthlate (B2EHP)	8.2E-05	2.0E-02	1,000	Liver	4E-03
Silver (AG)	4.7E-05	3.0E-03	2	Skin (Argyria)	2E-02
HAZARD INDEX	--	--	--	--	<1 (2E-02)

(a) The USATHAMA well Q20A is located along the service road and is currently closed.
(b) USATHAMA chemical codes listed in parentheses.
(c) EPA Weight of Evidence for Carcinogenic Effects: [B2] = Probable human carcinogen based on inadequate evidence from human studies and adequate evidence from animal studies.
(d) Factor which reflects the uncertainty in the estimate of the RfD. Larger factors are associated with greater uncertainty.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, an organ or organ system known to be affected by the chemical is listed.

remediation of 10^{-6}. For noncarcinogenic risks, the Hazard Index associated with ingestion of groundwater from this well for the RME case was well below a value of 1 (0.02). Therefore, noncarcinogenic effects associated with ingestion of groundwater from this well are not expected to occur. These chemicals would not volatilize to any significant degree, so no significant additional risks would result from other exposure routes (e.g., inhalation).

9.3.3.2.4 Potential Risks to Hypothetical Future On-Site Construction Workers.

The U.S. Air Force plans to construct a radio receiving station at Graces Quarters. The specific location of the station, construction plans, and time frame of the project are unknown. Construction activities in disposal and testing areas may result in exposure of construction workers via direct contact with surface and subsurface soils and inhalation of volatile organic chemicals. In addition, disturbing the subsurface soil would increase the chance of contacting unexploded ordnance and/or a chemical "hot spot" originating from possible bulk disposal of a chemical agent, although there are no reports of bulk disposal at Graces Quarters.

No surface or subsurface soil monitoring data were available for evaluating the potential impact on construction workers. In addition, no complete magnetometer surveys have been conducted at Graces Quarters to identify possible unexploded ordnance. Therefore, these potential subchronic and acute exposure pathways could not be quantitatively evaluated in this assessment. One soil sample was collected in 1977 and showed detected concentrations of hydrocarbons, benzene-related compounds, PAHs, phthalates, and PCBs. In addition, a soil gas survey conducted by NERI (1990) revealed that several plumes exist in the southern disposal area (i.e., primary test area and southern dump site). Subsurface soil contamination plumes consisted of BTX compounds (i.e., total of benzene, toluene, and xylenes), trichloroethene, tetrachloroethene, phthalates, and hydrocarbons. Many of these compounds are known or suspected carcinogens and may be released to air via volatilization or wind erosion. Construction workers may be at risk if they come in direct contact with contaminated soils and/or inhale volatilized chemicals in a confined excavated trench or foundation.

In addition, excavation activities may uncover unexploded ordnance or chemical "hot spots." The potential risks from fire and explosion include burns, injury, and death. Additionally, as listed in Table 9-1, principal compounds disposed of and/or used at the Graces Quarters study area include white phosphorus, distilled mustard, VX, sarin, and soman. Exposure to these chemicals may result in acute injuries to the eyes, skin, nose, throat, and/or lungs. For example, dermal contact with mustard may result in malaise, vomiting, fever, and inflammation and/or blistering of the eyes, skin, nose, throat, trachea, bronchi, and lung tissue. Higher doses of mustard may result in death or injury to bone marrow, lymph nodes, and spleen. The extent of contamination of subsurface soil must be delineated and complete magnetometer surveys performed in order to quantify this potentially important exposure pathway.

9.4 <u>ECOLOGICAL ASSESSMENT</u>

This section assesses ecological impacts associated with the chemicals of potential concern at Graces Quarters in the absence of remediation. The methods used to assess ecological impacts follow those outlined in Chapter 4 and roughly parallel those used in the human health risk assessment. Potentially exposed populations (receptors) were identified, then information on exposure and toxicity was combined to derive estimates of potential impact in these populations. It is emphasized that this ecological assessment is a predictive assessment. Comprehensive field studies of ecological impacts have not yet been conducted at Graces Quarters.

This ecological assessment is divided into four principal sections. Section 9.4.1 describes the habitat of the area and identifies the potential receptor species or species groups selected for evaluation. Section 9.4.2 evaluates and provides estimates of potential exposures for the chemicals and receptors of potential concern. Section 9.4.3 summarizes relevant toxicity information for the chemicals of potential concern, and Section 9.4.4 provides quantitative and qualitative estimates of ecological impact.

9.4.1 RECEPTOR CHARACTERIZATION

Graces Quarters is a mixture of forests, wetlands, and open fields. A mixed hardwood forest that covers over half of the study area is located in the higher elevations to the north. Shrubs and open meadows occupying approximately one-quarter of the area are located along the service road. Wetlands occupying the remaining quarter of the area are located in the lower elevation regions along the southern shoreline. The wetlands are influenced by the tidal effects of the Gunpowder River. No perennial surface water bodies are located on Graces Quarters. During the spring months, however, small ponds are formed when ditches and depressions collect surface water runoff during periods of heavy precipitation. Figure 9-2 depicts the principal habitat characteristics of Graces Quarters.

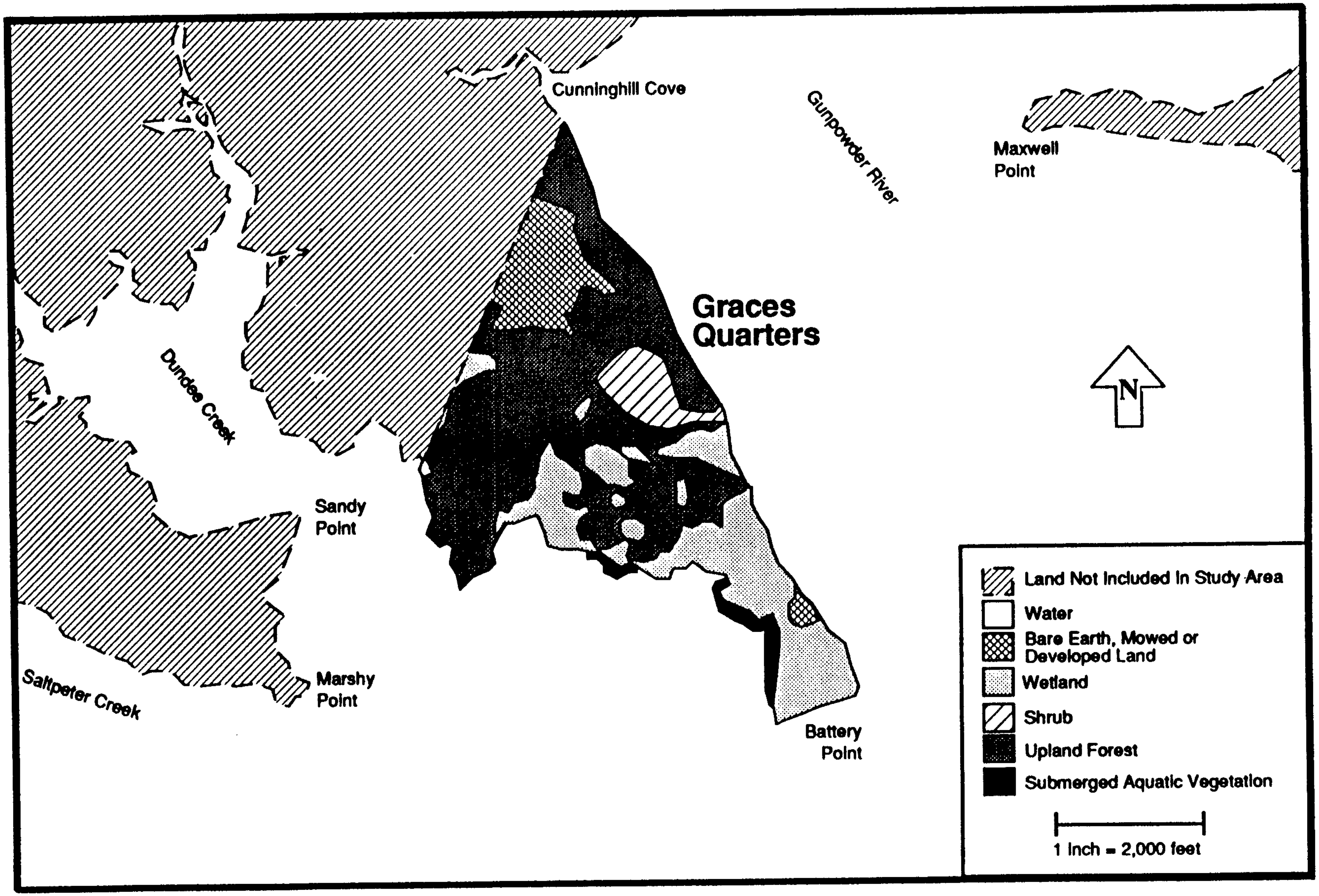
The different ecosystems of Graces Quarters support a variety of amphibians, reptiles, birds, and mammals. Amphibians in the forest and fields may include toads, newts, and salamanders, and black racers and box turtles are common reptiles that may be found at Graces Quarters. Bird species likely to inhabit the mixed hardwood forest and fields include the red-tailed hawk (*Buteo jamaicensis*), screech owl (*Otus asio*), crow (*Corvus brachyrhychos*), woodpeckers (e.g., downy woodpeckers [*Dendrocopos pubescens*] in the forest and flickers [*Colaptes auratus*] in the field), and passerines (e.g., warblers and thrushes in the forest and meadowlark and blackbirds in the field). Mammals that may be found in the mixed hardwood forest and fields of Graces Quarters include gray fox (*Urocyon cinereoargenteus*), white-tailed deer (*Odocoileus virginianus*), cotton-tailed rabbit (*Sylvilagus floridanus*) and a variety of mice, voles, and shrews.

The wetland areas may provide needed breeding and feeding areas for resident and migratory birds, as well as mammals, reptiles, and amphibians. Common amphibians that may be found in the wetlands include bullfrog, spring peeper, green frog, spotted salamander, and eastern newt. Reptiles resident to the wetlands may include eastern ribbon snake, brown water snake, painted turtle, mud turtle, spotted turtle, and snapping turtle. Birds likely to use the wetland areas include the great-blue heron (*Ardea herodias*) and other wading species, red-winged blackbird (*Agelaius phoeniceus*), marsh hawk (*Circus cyaneus*), herring gull (*Larus argentatus*), various species of dabbling ducks (*Anas platyrhynchos* and *Anas rubripes*), and a variety of shorebirds including spotted sandpiper (*Actitis macularia*). Bald eagles (*Haliaeetus leucocephalus*) also have been spotted at Graces Quarters. Mammalian species that may occupy the wetland areas include white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), masked shrew (*Sorex cinereus*), star-nosed mole (*Condylura cristata*), meadow vole (*Microtus pennsylvanicus*), beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*).

The seasonal surface water bodies located within the forest and fields may act as breeding grounds for amphibians and insect larvae. These surface water bodies are not expected to support fish.

Figure 9-2

Habitat Characteristics of the Graces Quarters Study Area At Aberdeen Proving Ground



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Common amphibians that may use these surface water bodies include the american toad, spring peeper, green frog, spotted salamander, and eastern newt.

The Gunpowder River provides aquatic habitat for a variety of freshwater and estuarine aquatic life. Freshwater and estuarine fish that may feed in the Gunpowder River near the Graces Quarters shoreline include white perch, Atlantic silverside, blueback herring, alewife herring, bay anchovy, Atlantic menhaden, mummichog, striped killifish, and channel catfish. White perch and bay anchovy may breed in the Gunpowder River near the Graces Quarters shoreline. Invertebrates that may be present in the Gunpowder River include polychaetes, isopods, amphipods, and chironomids.

As discussed in Chapter 4, it is not feasible to assess potential impacts in each of the species potentially present at Graces Quarters, and for this reason indicator species or species groups were selected for further evaluation. The selection of indicator species for Graces Quarters was driven by several factors, including the potential for exposure, the sensitivity or susceptibility to chemical exposures, the availability of toxicity data, the availability of chemical data for potential exposure media, ecological significance, and societal values. The indicator species or species groups selected for evaluation at Graces Quarters are a subset of those identified as potential indicators in Chapter 4 and are listed below along with the rationale for their selection.

Aquatic Species

Amphibians:

- Green frog. It may use the small seasonal on-site surface water bodies for breeding grounds.

Fish:

- Channel catfish. This species was selected for evaluation because of the availability of toxicity data and because it is a probable resident of the Gunpowder River along the shores of Graces Quarters.

- Herrings. The bay anchovy may use the Gunpowder River along the shores of Graces Quarters as a nursery area.

Invertebrates:

- Benthic invertebrates. They are susceptible to chemicals that may tend to concentrate in this zone. They also are an important component of the diet of many birds, as well as adult and juvenile fish.

Plants:

- Phytoplankton. This species group was selected for evaluation because of their importance in the aquatic food chain.

Terrestrial Species

Too few data are available with which to reliably evaluate exposures to any terrestrial wildlife species. Therefore, none are selected as indicator species.

The other species listed in Chapter 2 as potential indicator species were not selected for evaluation at Graces Quarters because optimal or preferred habitat is probably not contaminated (e.g., wetland areas as discussed in Section 9.4.2); they occur in the area but their exposures are likely to be less than or equal to that for a selected species; or no data were available for a media of concern (e.g., soil or sediments) and thus the pathway could not be evaluated.

Appendix D provides species profiles for the vertebrate species selected for evaluation. These profiles should be consulted for information on the ecology of the selected indicator species. Such profiles are not provided for benthic invertebrates or phytoplankton because of the large diversity of species comprising these broadly defined receptor groups.

9.4.2 POTENTIAL EXPOSURE PATHWAYS AND QUANTIFICATION OF EXPOSURE

After the potential receptors were identified, the pathways by which indicator species may be exposed to chemicals of potential concern were identified. Exposure pathways were identified after consideration of the sources, releases, types, and locations of the chemicals in each study area; the likely environmental fate and transport of the chemicals; and the location and activity of receptor populations.

Too few data (e.g., three surface water samples from the river, no soil samples) were available with which to evaluate terrestrial wildlife exposure, and thus, none are evaluated in this assessment.

Aquatic life could be exposed to chemicals of potential concern by respiration, direct contact with water and sediment, and ingestion of water (e.g., in filter feeders), sediments, and food containing chemicals of potential concern. However, most aquatic toxicity data that are available express toxicity (including AWQC) as a function of the concentration in the exposure medium (i.e., surface water or sediment concentrations). To be consistent with available toxicity data, exposures to aquatic life were evaluated in this assessment by using measured or estimated surface water concentrations. Tables 9-20 and 9-21 present the on-site and Gunpowder River surface water exposure concentrations, respectively. No recently collected, validated data are available for sediments; therefore, the potential impacts on aquatic life from contact with sediments were not evaluated.

No waste disposal activities occurred in the wetland areas. The impact of surface water runoff to the wetlands would probably be minimal given the distance from the disposal areas to the wetlands. Therefore, terrestrial wildlife in the wetlands (e.g., wading birds, muskrat) and aquatic life are not expected to be impacted by chemicals possibly released to the disposal and testing areas to the north. In addition, no surface water, sediment, or soil data were collected in the wetland area. Thus, this pathway was not evaluated in this assessment.

9.4.3 TOXICITY ASSESSMENT

In the toxicity assessment, the chemicals of potential concern are characterized with respect to their aquatic toxicity (no terrestrial wildlife exposure pathways were quantitatively evaluated in this assessment). Relevant toxicity data are summarized for each chemical of potential concern in Appendix C. Toxicity values for aquatic life were not developed for specific indicator species identified at Graces Quarters. Rather, toxicity values were derived for the most sensitive aquatic species, which is consistent with EPA regulatory approaches for protection of surface water quality. Acute and chronic toxicity values used in the assessment of aquatic life impacts from exposure to chemicals of

TABLE 9-20

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN ON-SITE SURFACE WATER AT GRACES QUARTERS

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
NORTHERN DISPOSAL SITE				
Organic Chemicals:				
bis(2-Ethylhexyl)phthalate (B2EHP)	3.6	6.4	4.7	4.7
Inorganic Chemicals:				
Aluminum (AL)	3,000	9,800,000	13,100	13,100
Copper (CU)	15	31	30.9	30.9
Iron (FE)	3,400	470,000	13,300	13,300
SOUTHERN DISPOSAL AREA				
Organic Chemicals:				
bis(2-Ethylhexyl)phthalate (B2EHP)	4.9	NA	7.6	7.6
Inorganic Chemicals:				
Aluminum (AL)	570	NA	662	662
Copper (CU)	6.8	NA	9.5	9.5
Iron (FE)	2,300	NA	3,220	3,220
Manganese (MN)	1,500	NA	2,400	2,400

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

NA = Not applicable; two samples only.

TABLE 9-21

EXPOSURE CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN IN GUNPOWDER RIVER SURFACE WATER AT GRACES QUARTERS

(Concentrations reported in ug/L)

Chemical (a)	Arithmetic Mean	Upper 95 Percent Confidence Limit on the Arithmetic Mean (b)	Maximum Detected Concentration	RME Concentration (c)
NORTHERN DISPOSAL AREA				
Inorganic Chemicals:				
Aluminum (AL)	1,300	NA	2,020	2,020
Cadmium (CD)	7.1	NA	12.2	12.2
Copper (CU)	23	NA	31.2	31.2
Iron (FE)	2,600	NA	4,020	4,020
Nickel (NI)	37	NA	53.1	53.1
SOUTHERN DISPOSAL AREA				
Organic Chemicals:				
bis(2-Ethylhexyl)phthalate (B2EHP)	--	--	5.9	5.9
Inorganic Chemicals:				
Aluminum (AL)	--	--	815	815
Cadmium (CD)	--	--	4	4
Copper (CU)	--	--	12.2	12.2

(a) USATHAMA chemical codes listed in parentheses.
(b) Values reflect a positively skewed distribution.
(c) Value listed is the lower value of the upper 95 percent confidence limit on the arithmetic mean and the maximum detected value.

NA = Not applicable; two samples only.
-- = Not applicable; single sample.

potential concern in surface water are presented in Tables 9-22 and 9-23, respectively. The methodology for deriving these toxicity values is discussed below. As previously discussed, sediment data were not available at Graces Quarters, so no aquatic toxicity values were developed for sediment.

AWQC were used to assess potential impacts to aquatic life when available. AWQC were derived to prevent unacceptable toxic effects for 95% of all families of aquatic vertebrates (fish [and amphibians for some chemicals]), invertebrates, and plants (Stephens et al. 1985, EPA 1986c), and therefore are regarded in this assessment as sufficiently protective of all families of species at APG.

In this assessment, AWQC were available for all chemicals selected as chemicals of potential concern in surface water with the exception of iron (an acute AWQC was not available) and manganese (acute and chronic AWQC were not available). Acute toxicity values for iron and manganese were derived using the available literature and following the methodology outlined in Chapter 4. The numbers derived using this approach are conceptually similar to an AWQC and are meant to provide concentration levels that are protective of the majority of aquatic species across all receptor groups (i.e., fish, invertebrates, and plants). It should be noted that the derived acute toxicity criterion for iron is less than the chronic AWQC (see Appendix C for a discussion of the derivation of the chronic toxicity value). This reflects the uncertainty in the approach used for toxicity assessment when adequate toxicity data are not available.

9.4.4 POTENTIAL ECOLOGICAL IMPACTS

This section evaluates the potential ecological impacts on aquatic life by comparing surface water toxicity values to surface water concentration data.

Concentrations of chemicals of potential concern detected in on-site ditches were compared to fresh-water aquatic toxicity values, as presented in Table 9-24. The exposure point concentrations estimated for aluminum, copper, and iron in the northern and southern disposal areas exceeded both acute and chronic toxicity criteria (with the exception of the concentration of aluminum in the southern disposal area, which did not exceed the acute toxicity value). Additionally, the exposure point concentration for manganese in the southern disposal area exceeded both acute and chronic toxicity criteria. Therefore, aquatic life that may inhabit these seasonal ditches (e.g., frogs eggs, salamander eggs, insect larvae, and algae) may be adversely impacted under chronic and potentially acute exposure conditions. The highest detected concentrations of these inorganic chemicals (except manganese) were found in ditches below the northern dump site. The exposure point concentrations for bis(2-ethylhexyl)phthalate in the northern and southern disposal area did not exceed acute or chronic toxicity values. The potential impact to the population of freshwater aquatic life at Graces Quarters is probably minimal given the availability of other more suitable spawning areas for frogs and salamanders.

Concentrations of chemicals of potential concern detected in the Gunpowder River near the northern and southern disposal areas were compared to aquatic toxicity values as presented in Table 9-25. The exposure point concentrations estimated for aluminum, cadmium, and copper (in the northern and southern disposal areas) and iron (in the northern disposal area only) exceeded both acute and chronic toxicity criteria. The exposure point concentration of nickel in the northern disposal area exceeded the chronic toxicity value but not the acute value. Therefore, estuarine aquatic life that may live along the shores of Graces Quarters may be adversely impacted under chronic and potentially acute exposure conditions. The exposure point concentration for bis(2-ethylhexyl)phthalate detected

TABLE 9-22

ACUTE TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT GRACES QUARTERS

Chemical (a)	Acute Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
bis(2-Ethylhexyl)phthalate (B2EHP)	400	Proposed AWQC (freshwater)	EPA (1987)
Inorganic Chemicals:			
Aluminum (AL)	750	AWQC (freshwater)	EPA (1988)
Cadmium (CD)	2.3 (d)	AWQC (freshwater)	EPA (1985a)
Copper (CU)	7.5 (e)	AWQC (freshwater)	EPA (1985b)
	2.9	AWQC (saltwater)	EPA (1985b)
Iron (FE)	320	96-hour LC50 in aquatic insects	Warnick and Bell (1969) in EPA (1976)
Manganese (MN)	1,450	96-hour LC50 in rainbow trout	Davies (1980)
Nickel (NI)	75	AWQC (saltwater)	EPA (1986b)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Hardness dependent criterion (hardness of 40 mg/L as $CaCO_3$ used as lower limit).
(e) Hardness dependent criterion (hardness of 63 mg/L as $CaCO_3$ used as lower limit).

AWQC = Ambient Water Quality Criteria.

TABLE 9-23

CHRONIC TOXICITY VALUES FOR ASSESSMENT OF AQUATIC LIFE IMPACTS FROM EXPOSURE TO CHEMICALS IN SURFACE WATER AT GRACES QUARTERS

Chemical (a)	Chronic Toxicity Value (b) (ug/L)	Basis for Value (c)	Reference
Organic Chemicals:			
bis(2-Ethylhexyl)phthalate (B2EHP)	360	Proposed AWQC (freshwater)	EPA (1987)
Inorganic Chemicals:			
Aluminum	87	AWQC (freshwater)	EPA (1988)
Cadmium (CD)	0.8 (d)	AWQC (freshwater)	EPA (1985a)
Copper (CU)	5.4 (e)	AWQC (freshwater)	EPA (1985b)
	2.9 (f)	AWQC (saltwater)	EPA (1985b)
Iron (FE)	1,000	AWQC (freshwater)	EPA (1986c)
Manganese (MN)	10	Growth reduction in Pacific oyster larvae exposed for 14-days	Watling (1983) in AQUIRE (1990)
Nickel	8.3	AWQC (saltwater)	EPA (1986b)

(a) USATHAMA chemical codes listed in parentheses.
(b) Derived using the methodology outlined in Chapter 4.
(c) See Appendix C for more detailed study information.
(d) Hardness dependent criterion (hardness of 63 mg/L as $CaCO_3$ used as lower limit).
(e) Hardness dependent criterion (hardness of 40 mg/L as $CaCO_3$ used as lower limit).
(f) Acute saltwater AWQC presented. No chronic AWQC for saltwater aquatic life available.

AWQC = Ambient Water Quality Criteria.

TABLE 9-24

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH ON-SITE SURFACE WATER CONCENTRATIONS AT GRACES QUARTERS

(Concentrations reported in ug/L)

Chemicals of Potential Concern (a)	Exposure Concentrations in On-Site Ditches (b)		Surface Water Toxicity Criteria (c)		Toxicity Value Exceeded	
	Northern Disposal Area	Southern Disposal Area	Acute	Chronic	Northern Disposal Area	Southern Disposal Area
Organic Chemicals:						
bis(2-Ethylhexyl)phthalate (B2EHP)	4.7	7.6	400	360	--	--
Inorganic Chemicals:						
Aluminum (AL)	13,100	662	750	87	Acute, Chronic	Chronic
Copper (CU)	30.9	9.5	7.5	5.4	Acute, Chronic	Acute, Chronic
Iron (FE)	13,000	3,220	320	1,000	Acute, Chronic	Acute, Chronic
Manganese (MN)	NA	2,400	1,450	10	NA	Acute, Chronic

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Table 9-20.
(c) Reported previously in Tables 9-22 and 9-23.

NA = Not applicable. Not selected as a chemical of potential concern.
-- = No toxicity value exceeded.

TABLE 9-25

COMPARISON OF AQUATIC LIFE TOXICITY VALUES WITH GUNPOWDER RIVER SURFACE WATER CONCENTRATIONS AT GRACES QUARTERS

(Concentrations reported in ug/L)

Chemicals of Potential Concern (a)	Exposure Concentrations in Gunpowder River (b)		Surface Water Toxicity Criteria (c)		Toxicity Value Exceeded	
	Northern Disposal Area	Southern Disposal Area	Acute	Chronic	Northern Disposal Area	Southern Disposal Area
Organic Chemicals:						
bis(2-Ethylhexyl)phthalate (B2EHP)	NA	5.9	400	360	NA	--
Inorganic Chemicals:						
Aluminum (AL)	2,020	815	750	87	Acute, Chronic	Acute, Chronic
Cadmium (CD)	12.2	4.0	2.3	0.8	Acute, Chronic	Acute, Chronic
Copper (CU)	31.2	12.2	2.9	2.9	Acute, Chronic	Acute, Chronic
Iron (FE)	4,020	NA	32	1,000	Acute, Chronic	NA
Nickel (NI)	53.1	NA	75	8.3	Chronic	NA

(a) USATHAMA chemical codes listed in parentheses.
(b) Reported previously in Table 9-21.
(c) Reported previously in Tables 9-22 and 9-23.

NA = Not applicable. Not selected as a chemical of potential concern.
-- = No toxicity value exceeded.

in the Gunpowder River along the shores of the southern disposal area did not exceed acute or chronic toxicity values.

It is not possible to assess the effects of aquatic life impacts in the Gunpwder River, given the limited available data, because the extent of contamination in the Gunpowder River is not known (i.e., only 3 surface water samples and no sediment samples available). Impacts will be significantly less if contamination is limited to portions of the Graces Quarters shoreline. If, however, contamination extends a significant distance into the Gunpowder River, more extensive impacts are possible.

9.5 UNCERTAINTIES

As in any risk assessment, there is a large degree of uncertainty associated with the estimates of human health and ecological risks for the Graces Quarters study area. Consequently the risk estimates should not be regarded as absolute estimates of risk but rather as conditional estimates based on a number of assumptions regarding exposure and toxicity. A complete understanding of the uncertainties associated with the risk estimates is critical to understanding the true nature of the predicted risks and to placing the predicted risks in proper perspective. The principal sources of uncertainty associated with the APG risk assessments were discussed in Chapter 4. Some of the key sources of uncertainty associated with the estimates of risk for the Graces Quarters study area are summarized below.

9.5.1 UNCERTAINTIES RELATED TO SELECTION OF CHEMICALS FOR EVALUATION

Site-specific background data were not collected from any of the media sampled. Consequently data from the literature that may not be especially representative of local background concentrations were used to determine if a chemical could be site related. Because only one inorganic chemical contributed to the risk for the pathways evaluated (thallium in groundwater in the surficial aquifer), the impact of this on the risk assessment may be negligible.

Although historical information indicates that phthalates were used at Graces Quarters, it is not known if the bis(2-ethylhexyl)phthalate detected in groundwater and surface water is related to laboratory contamination or to the site. No trip or field blank information was available for the samples that were collected as part of the USGS (1990) hydrogeologic study used in this assessment (groundwater and surface water). Additionally, these groundwater and surface water samples were analyzed only for inorganic chemicals, volatile organic chemicals, and semivolatile organic chemicals. These samples were not analyzed for chemical agents, agent degradation products, pesticides, or radioactivity.

At this time, the quantitative evaluation of potential risks at the Graces Quarters study area is limited due to lack of data on soil, sediment, and air. Soil and sediment samples were collected during the study conducted by the USGS (1990) but have not yet been made available. Due to this lack of data, potential risks associated with these media could not be quantitatively evaluated in this assessment.

9.5.2 UNCERTAINTIES ASSOCIATED WITH THE ASSUMPTIONS USED TO ESTIMATE EXPOSURES

A large degree of uncertainty associated with the risk estimates for ingestion of groundwater is associated with the exposure point concentrations. Actual concentrations of chemicals in wells that may hypothetically be used in the future may be different than those used in this evaluation. As stated above, the groundwater samples were analyzed for a limited number of chemicals; chemicals associated with chemical agents, agent degradation products, pesticides, and radioactivity that may potentially be present in the groundwater were not analyzed for. Additionally, results of a soil gas survey indicate that the highest concentrations of volatile organic chemicals in groundwater may be in some areas where groundwater wells have not been installed, indicating that the potential risks from ingesting groundwater may actually be higher than determined in this risk assessment. Finally, chemicals that may also be present in soil (and which are not yet defined) may serve as a continuing source of groundwater contamination.

9.5.3 UNCERTAINTIES IN THE TOXICITY ASSESSMENT

Uncertainties in the toxicity assessment are discussed generally in Chapter 4. For this assessment, of the chemicals of potential concern that were selected to be quantitatively evaluated to assess potential human health risks from ingestion of groundwater, aluminum and iron could not be evaluated due to lack of toxicity criteria. The overall effect of not evaluating these chemicals results in an underestimate of risk. However, this underestimate is expected to be negligible given the conservative nature of the exposure parameters.

9.6 PRINCIPAL DATA NEEDS

Investigations to date have not provided a complete and exhaustive characterization of the type and extent of contamination at Graces Quarters. As a result, additional investigation is needed to assess more definitely existing or potential impacts associated with the Graces Quarters study area. The principal types of additional data needed to evaluate impacts at this study area are data on the nature and extent of contamination. Specific data needs are summarized below.

- For all of the environmental sampling recommended below, samples should be analyzed for inorganic chemicals, volatile organic chemicals, semivolatile organic chemicals, PCBs, pesticides, radionuclides, and the range of military-unique compounds present or suspected to be present at the Graces Quarters study area as well as their degradation products.

- For each media sampled, background samples should also be collected for analysis. It is recognized that due to the potential for widespread contamination at APG, it may not be possible to collect representative background samples from, or close to, the Graces Quarters study area. However, an attempt should be made to characterize background concentrations as well as possible. For example, for soil, background samples should be of the same soil type, and background surface water and sediment samples should be collected from similar tidal creek systems as those surrounding the Graces Quarters study area.

- Because soil sampling data are not available, the adequacy of these data cannot be evaluated. However, as mentioned above, it is likely that additional soil samples (both surface and subsurface) will need to be collected and analyzed for additional chemicals such as PCBs, pesticides, radionuclides, and for the range of military-unique compounds present or suspected to be present at the Graces Quarters study area as well as their degradation products.

- Additional surface water and sediment samples are needed from the Gunpowder River near the northern and southern disposal areas to help define the extent of contamination in these areas.

- Although no significant impact is expected from Dundee or Saltpeter Creeks, surface water and sediment samples should be collected from these water bodies to confirm that they are not contaminated.
- Additional groundwater wells should be installed to better define the contaminant migration and groundwater surface water interaction. Results of a soil gas survey indicate two areas of volatile organic contamination in the groundwater in which there are no monitoring wells.
- Information should be gathered on the nearby groundwater well at Gunpowder Falls State Park to provide support for not evaluating potential exposure through ingestion of groundwater from this well.
- If possible, additional information concerning disposal activities at the Graces Quarters dump, the secondary test area, the northern dump, and the southern dump should be gathered.
- Once the contamination at Graces Quarters is well defined, additional recommendations can be made concerning data related to wildlife exposures and/or impacts.

9.7 SUMMARY AND CONCLUSIONS

This baseline risk assessment addressed the potential impacts on human health and the environment associated with the Graces Quarters study area in absence of remedial actions. The principal data used in this assessment were collected during the hydrogeological investigation conducted by USGS (1990). Only groundwater and surface water monitoring results were available from this study. Soil and sediment samples were also collected during the USGS (1990) study, but these monitoring results were not available during preparation of this report. Of the samples that were collected, chemical analyses were limited primarily to inorganic chemicals, and volatile and semivolatile organic chemicals.

9.7.1 HUMAN HEALTH RISK ASSESSMENT SUMMARY

Many of the potential exposure pathways by which human populations could be exposed to chemicals of potential concern under current land-use conditions of the Graces Quarters study area were not evaluated due to the negligible potential for significant exposure. This decision was based primarily on the infrequent use of specific areas and, in some instances, lack of data. The potential impact to people who ingest fish caught along the Graces Quarters shoreline was evaluated qualitatively under current land-use conditions. Under future land-use conditions the primary pathways by which individuals could potentially be exposed to chemicals of potential concern from the Graces Quarters study area are: ingestion of groundwater from the surficial aquifer, confined aquifer, or the existing USATHAMA well; direct contact with soil and/or inhalation of dust and volatile organic chemicals by future on-site construction workers; and/or acute dermal and/or inhalation exposure resulting from an instantaneous explosive release and/or chemical release. Potential risks from hypothetical future ingestion of groundwater were evaluated quantitatively, and chronic risks to future workers through dermal contact with soil, and inhalation, as well as acute risks were qualitatively evaluated.

The estimated human health risks associated with these pathways are as follows:

Current Land Use

- Ingestion of fish from the Gunpowder River along the shore of the southern disposal area could pose potential carcinogenic and noncarcinogenic risks, primarily due to the presence of bis(2-ethylhexyl)phthalate. However, the extent of bis(2-ethylhexyl)phthalate contamination in the Gunpowder River is unknown. If contamination is limited to the Graces Quarters shoreline, significant accumulation in sport and commercial fish of the area is unlikely. TCPU may also potentially contribute to the risk from ingestion of fish, but the potential bioaccumulation and toxicity of TCPU are unknown.

Future Land Use

- The total excess cancer risk from ingestion of groundwater from the surficial aquifer for the RME case is $3x10^{-4}$. Most of the carcinogenic risk was associated with exposure to carbon tetrachloride and 1,1,2,2-tetrachloroethane. For noncarcinogenic risks, the Hazard Index associated with ingestion of groundwater from the surficial aquifer exceeded 1, indicating that noncarcinogenic risks may occur.

- The total excess cancer risk from ingestion of groundwater from the confined aquifer for the RME case is $2x10^{-6}$. Most of the carcinogenic risk was associated with exposure to 1,1,2,2-tetrachloroethane. The Hazard Index was less than 1, indicating that noncarcinogenic effects are not likely.

- The total excess cancer risk from ingestion of groundwater from USATHAMA well Q20A is $3x10^{-7}$. For noncarcinogenic risks, the Hazard Index was less than 1, indicating that noncarcinogenic effects are not likely.

- Future workers at the Graces Quarters study area may encounter chronic or acute exposures during construction activities through direct contact with soil, inhalation, fire, or explosion. Known or suspected carcinogens, such as benzene, trichloroethene, tetrachloroethane, and phthalates, were detected in subsurface. An instantaneous explosive release and/or evaporative release could potentially result in burns, dismemberment, acute injuries to the eyes, skin, nose, throat, lungs, and/or death.

9.7.2 ECOLOGICAL ASSESSMENT SUMMARY

Potential ecological impacts were evaluated for aquatic life at the Graces Quarters study area. Too few data were available to assess potential terrestrial wildlife exposures.

Federal ambient water quality criteria (AWQC) were used to assess potential impacts to aquatic life when available; other toxicity values were derived using a standard approach. Concentrations of chemicals of potential concern in the water bodies sampled were compared to aquatic toxicity values. Concentrations of several inorganic chemicals exceeded aquatic toxicity values.

9.7.3 CONCLUSIONS OF THE RISK ASSESSMENT

Past activities at Graces Quarters have resulted in contamination of groundwater and surface water of the area. The extent of contamination in other media is unknown. Few human exposure pathways exist under current land-use conditions, and those that do exist are unlikely to result in significant exposures or risks. Additional human health risks could be possible if human use of Graces Quarters changes in the future. In particular, use of groundwater from the area could be associated with significant human health risks.

Aquatic life in seasonal on-site ponded areas and along the Gunpowder River shoreline could be impacted by chemicals present in these surface waters. Impacts associated with the on-site ponded areas are unlikely to significantly affect seasonal aquatic populations at Graces Quarters (e.g, frogs, insects), given the wide-availability of more suitable aquatic habitat across Graces Quarters. The extent of aquatic life impacts in the Gunpowder River cannot be evaluated at this time because the extent of contamination in the river is unknown. Significant impacts could result if contamination extends far out into the river; much smaller impacts are likely if contamination is limited to the shoreline area. Impacts in terrestrial wildlife living or feeding at Graces Quarters could not be evaluated because of insufficient sampling data.

Additional data are needed for a more complete evaluation of the potential human health and ecological impacts associated with the Graces Quarters study area.

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