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U.S. Army Environmental Center

REMEDIAL INVESTIGATION
BADGER ARMY AMMUNITION PLANT
BARABOO, WISCONSIN

FINAL
REMEDIAL INVESTIGATION REPORT

DATA ITEM A011

VOLUME I OF II
TEXT SECTIONS 1 THROUGH 12

Unlimited Distribution
Approved for Public Release

CONTRACT DAAA15-91-D-0008
U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND

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APRIL 1993

Printed on recycled paper

U.S. Army Environmental Center

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DATA ITEM A011

CONTRACT DAAA15-91-D-0008
TASK ORDER 1

Prepared for:

United States Army
Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

Prepared by:

ABB Environmental Services, Inc.
Portland, Maine
Project No. 6853-10

APRIL 1993

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INTRODUCTION

ABB Environmental Services, Inc. (ABB-ES) prepared this Remedial Investigation (RI) report on the Badger Army Ammunition Plant (BAAP) to support Task Order 1 of Contract DAAA15-91-D-0008 with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). This report details the results of the RI program at BAAP, which was completed in accordance with current relevant U.S. Environmental Protection Agency (USEPA) guidance.

This RI report describes the site data gathered, evaluated, and assessed during RI activities to meet federal permit conditions issued by USEPA Region V (USEPA, 1988a) under authority of the Resource Conservation and Recovery Act, and requirements set forth by the Wisconsin Department of Natural Resources (WDNR) in the In-field Conditions Report (WDNR, 1987) and subsequent modifications (February 1990, November 1991, March 1992, and October 1992) under authority of the Wisconsin Environmental Response and Repair Regulations. BAAP is not currently on, or proposed for, the National Priorities List. The RI activities were designed and conducted by USATHAMA under the National Contingency Plan (NCP) 40 CFR 30 to meet the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This RI Report has been completed in accordance with current CERCLA guidance.

The scope of work for this RI at BAAP was specified by USATHAMA based on previous site studies and investigations, knowledge of site manufacturing processes and operations, suspected source areas of potential contaminant releases, and identification of data gaps described in the Master Environmental Plan (MEP) prepared by Argonne National Laboratory in conjunction with recommendations by ABB-ES. USATHAMA directed this RI at BAAP to determine the extent of chemical contamination that exists because of past disposal practices and plant operations.

BAAP is a large industrial installation in south-central Wisconsin, approximately 9 miles south of Baraboo and 30 miles northwest of Madison. BAAP covers approximately 7,354 acres within Sumpter and Merrimac townships in Sauk County. The installation is bounded by U.S. Route 12 on the west, Devil's Lake State Park on the north, and privately owned farmland on the south and east. State Highway 78 and Lake Wisconsin define the southeastern plant boundary. The installation is entirely fenced and access by the public is controlled. A non-military security force maintains a 24-hour patrol seven days per week.

EXECUTIVE SUMMARY

BAAP has had three active production periods since its construction in 1942: World War II (1943 to 1945), the Korean Conflict (1951 to 1953), and the Vietnam Conflict (1966 to 1975). During these periods, various formulations of Nitrocellulose (NC) based propellants were produced including single base artillery propellant, double base solventless rocket propellant and double base ball propellant. Intermediate materials used in the manufacture of these propellants were also produced including nitroglycerine (NG), sulfuric acid, and nitric acid. Chemicals of potential concern include NG, NC, acids, dinitrotoluenes (DNTs), diphenylamine, nitrosamines, carbon tetrachloride (CCL4), chloroform (CHCL3) trichloroethylene (TRCLE), benzene (C6H6), lead (PB), mercury (HG), nitrite/nitrate nonspecific (NIT), and sulfate (SO4). Previous investigations documented that these chemicals exist in soils and groundwater at BAAP.

The MEP identified nine solid waste management units (SWMUs) that required additional study to close existing data gaps. These are: the (1) Propellant Burning Ground including Landfill 1, (2) Settling Ponds and Spoils Disposal Area, (3) Deterrent Burning Ground, (4) Existing Landfill, (5) Rocket Paste Area, (6) Nitroglycerine Pond, (7) Acid Areas, and (8) Oleum Plant and Oleum Plant Pond, and (9) Ballistics Pond. The Acid Areas were subsequently divided into the Old Acid Area and the New Acid Area after completion of the MEP. The Old Fuel Oil Tank, the site of a possible fuel oil spill or leak and a former aboveground fuel storage tank, was subsequently added to the list of SWMUs by USATHAMA, bringing the number of SWMUs to 11.

The RI consisted of the following activities:

- site reconnaissance
- review of existing data and investigations
- soil vapor and geophysical surveys
- surface and subsurface soil sampling and analysis
- surface water and sediment sampling and analysis
- soil borings and monitoring well installations
- two complete rounds of groundwater sampling and analysis
- horizontal location and vertical elevation survey of the explorations
- aquifer pumping test and analysis

BAAP GEOLOGY

The BAAP geologic setting is generally characterized by a sequence of unconsolidated soil units probably deposited in association with late Quaternary glacial advance and retreat. At the ground surface across most of BAAP, a 5- to 10-foot-thick fine-grained clayey silt unit (i.e., loess) overlies glacially derived soil deposits. The unconsolidated glacial deposits thicken from north to south across BAAP. Along the northern site boundary, soil deposits are thin or absent and bedrock outcrops are common. However, the bedrock surface dips steeply toward the south and soil deposits quickly thicken to a maximum of approximately 250 feet.

Bedrock geology at BAAP beneath unconsolidated soils is dominated by sandstones from the Eau Claire Formation of the Dresbach Group throughout most of the site, with quartzites from the Baraboo Formation and quartzite conglomerates along the northern boundary of the site.

BAAP HYDROGEOLOGY

The groundwater flow system beneath BAAP is unconfined and receives recharge from infiltrating precipitation. Infiltration is restricted, however, by a fine-grained loess layer at the ground surface. Below the loess, a relatively thick coarse-grained unsaturated zone exists above the water table. Groundwater exists in both the unconsolidated sand and gravel aquifer and the consolidated sandstone bedrock aquifer beneath this unsaturated zone. In the northern portions of BAAP, it appears the high bedrock surface elevation and the presence of thin, discontinuous layers of fine-grained glaciolacustrine soils limit the downward movement of groundwater, resulting in a higher water table elevation with a steep gradient in the northern portion of the installation. The gradient of the water table flattens substantially, and the flow direction changes from southeasterly to southerly across the central and southern portions of the facility.

Groundwater flow in the eastern portion of BAAP is influenced by the Wisconsin Power and Light (WP&L) dam on the Wisconsin River. Along the eastern boundary of BAAP, groundwater flows generally parallel to the river. This condition extends south of BAAP to the WP&L dam. South of the dam, the groundwater flow direction turns east, resulting in groundwater discharge to the Wisconsin River immediately below the dam.

The following sections provide an overview of the hydrogeology, contamination assessment, and human and ecological risk assessment of each site at BAAP. The contamination assessment describes contaminant distribution and interpretation at the 11 SWMUs, as well as in the installation-wide groundwater flow system and the off-post area south of BAAP. Concentrations of the various chemicals of concern are referenced to background concentrations as measured in site and regional background surface soil, subsurface soil, sediments, surface water, and groundwater, and to Wisconsin Preventive Action Limits (WPALs) and Wisconsin Enforcement Standards (WESs).

A human health evaluation, conducted according to current USEPA guidance, assessed the potential human health risks associated with the 11 SWMUs at BAAP. This process consisted of (1) selection and toxicological evaluation of chemicals of concern, (2) selection of exposure scenarios and quantification of exposure to chemicals present at BAAP, and (3) the evaluation of human health risks specific to each of the 11 sites at BAAP.

The ecological risk assessment for BAAP is primarily based on modeling. No actual testing of biota was completed as part of the RI. However, deer tissue analysis for DNTs conducted by U.S. Army Environmental Hygiene Agency (USAEHA) were evaluated and included as part of the ecological risk assessment.

The Baseline Ecological Assessment conducted for BAAP generated Hazard Indices (HIs) for a sensitive representative biological receptor. The HIs generated under the most-probable scenario indicate that site-associated chemical contamination likely results in some toxicological effects on both aquatic and terrestrial biota at some of the 11 SWMUs.

Propellant Burning Ground Landfill No. 1, and Settling Ponds and Spoils Disposal Area

Hydrogeologic analysis at the Propellant Burning Ground and Settling Ponds and Spoils Disposal Area indicates that groundwater flow is generally toward the south and parallel to the Lake Wisconsin Reservoir. Groundwater from these areas likely discharges to the Wisconsin River south of the WP&L dam. Groundwater flow velocity for this area is in the range of 250 to 400 feet per year (ft/yr).

Principal groundwater contaminants identified at the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Areas (Section 6.0) are volatile organic compounds (VOCs), TRCLE, CCL4, CHCL3, C6H6, and 1,1,1-trichloroethane (111TCE); semivolatile organic compounds (SVOCs), 2,6-dinitrotoluene (26DNT), n-nitrosodiphenylamine (NNDPA), NIT, SO4, and metals PB, cadmium (CD), and chromium (CR). The principal VOCs detected in groundwater include TRCLE, CCL4, and CHCL3. These contaminants were detected in and characterized as a plume extending southward from the Propellant Burning Ground beneath the Settling Ponds and off-post south of BAAP. 26DNT was detected in groundwater samples collected from several wells near the contaminated waste disposal area; the highest concentrations were detected downgradient of the Contaminated Waste Area. Inorganic compounds identified (above background or state and federal standards) in groundwater include NIT detected in groundwater samples collected south and southeast of the Propellant Burning Ground and Settling Ponds; and SO4 in the vicinity of the racetrack. The metals PB, CD, and CR were detected in groundwater, but had no observed spatial or temporal pattern and are therefore not considered to be site-related contaminants.

VOCs, DNTs, and some metals (i.e., PB, CR, copper [CU], and zinc [ZN]) were detected in surface soil at the Propellant Burning Ground. VOCs, primarily TRCLE, and DNTs identified at relatively high concentrations in subsurface soil at the Propellant Burning Ground. These high concentrations of VOCs and DNT in soil appear to be a source of TRCLE and DNT found in groundwater. Metals and DNTs were also detected in surface soil in the burning pads area. Although the presence of CCL4 in groundwater is extensive, no apparent localized source of CCL4 in surface or subsurface soils was identified to account for groundwater contamination.

The Human Health Evaluation indicates carcinogenic risks can be expected from ingestion of 24DNT in surface soil at Settling Pond 1. The presence of PB in soils at the Propellant Burning Ground presents noncarcinogenic risks to human health.

Negative impacts to terrestrial organisms, based on conservatively parameterized computer food web modeling, were predicted to be most severe at the Propellant Burning Ground. In addition, detrimental effects on plants due to PB concentrations (100 and 400 ppm) in soil could be expected in the Propellant Burning Ground.

Deterrent Burning Ground and Existing Landfill

Hydrogeologic analysis at the Deterrent Burning Ground and Existing Landfill indicates that fine-grained lacustrine layers at or immediately above the regional water table serve to elevate or perch groundwater, resulting in a localized flow system that flows to the northeast from the Deterrent Burning Ground toward the Existing Landfill and the eastern boundary of BAAP. This localized flow system, has not been fully characterized off post and east of the Existing Landfill. Outside the area of this localized flow system, groundwater within the regional system flows south and southeast with a flat gradient. Groundwater flow velocities in the regional system are on the order of 300 to 350 ft/yr.

At the Deterrent Burning Ground and Existing Landfill, principal groundwater contaminants identified were 111TCE, NNDPA, 26DNT, NIT, and SO4. The highest concentrations of these contaminants were detected primarily in the localized, elevated flow system. A source of 111TCE was not identified in subsurface soils collected for analysis. The regional flow system below the silty clay/silty sand aquitard does not appear to be contaminated with SO4 and NIT above existing regulatory groundwater standards that are protective of human health. However, NIT and SO4 contaminated groundwater may be "leaking" from the localized, elevated flow system to the underlying regional flow system, where mixing and dilution results in undetectable concentrations in the regional flow system. DNTs detected in soil at the Deterrent Burning Ground are likely the source of 26DNT in groundwater. The Deterrent Burning Ground is likely a contributing source of SO4 contamination in the localized, elevated flow system.

The RI Human Health Evaluation indicates carcinogenic risks could be expected from ingestion of 24DNT in subsurface soil at the Deterrent Burning Ground. The Ecological Risk Assessment at the Deterrent Burning Ground indicates potential detrimental effects to plants due to high concentrations of PB in subsurface soils associated with the former deterrent burning pits.

New Acid Area, Nitroglycerine Pond and Rocket Paste Area

At the New Acid Area, Nitroglycerine Pond, and Rocket Paste Area, groundwater generally flows from north to south and water table gradients are very flat. Groundwater in these areas is likely recharged by water that collects in the Rocket Paste Pond and ditches and the Nitroglycerine Pond, as well as by precipitation that falls on these areas. Calculated groundwater flow velocities in these three areas range from 250 to 400 ft/yr.

The distribution and extent of contamination at the Nitroglycerine Pond and the Rocket Paste Area is consistent with observations from previous studies of the impacts associated with production activities conducted in these areas. HG and trace levels of NG were found in Nitroglycerine Pond sediments. It is likely that detected HG is an artifact of NG purity tests performed during periods of production.

PB was detected in the Nitroglycerine Pond drainage ditch at the effluent outfall from the rocket paste blend houses. Concentrations of PB up to 1,000 micrograms per gram (equivalent to parts per million [ppm]) were also detected in sediment from the Rocket Paste Pond.

Drainage ditch sediment samples from the Western Rocket Paste Area also contained PB, as well as trace concentrations of diethylphthalate (DEP), NNDPA, and NG. No DNTs were detected in any ditch sediment samples collected from the Western Rocket Paste Area. These findings support the reported information that the drainage ditches were excavated in an attempt to remove residual rocket paste from this area.

In contrast, drainage ditch sediment samples from the Eastern Rocket Paste Area contained high concentrations of PB, 24DNT, NNDPA and NG, and low concentrations of DEP. This suggests that, unlike the Western Rocket Paste Area, the Eastern Rocket Paste Area drainage ditches were not excavated to remove residual rocket paste that accumulated during production activities. Concentrations of rocket paste-related chemicals found in the Eastern Rocket Paste Area indicate that a significant source of potential contamination still exists in this area of BAAP.

Groundwater in the Nitroglycerine Pond and Rocket Paste Area was found to contain NIT at concentrations exceeding the WPAL. However, these concentrations may be a result of agricultural activities and not BAAP production of propellants. DNTs were not detected in groundwater even though they were found at high concentrations in sediments. PB was detected at concentrations exceeding the WPAL, but less than the WES, in groundwater samples immediately downgradient of the Rocket Paste Pond.

Groundwater at the New Acid Area appears to have been affected by past operations. NIT and SO4 have been detected above regulatory standards in groundwater at the New Acid Area. Review of historical data associated with the New Acid Area indicated that concentrations of NIT and SO4 in groundwater have resulted in only marginal exceedances of the regulatory standards. Concentrations of SO4 and NIT above background values may exist in groundwater downgradient of the New Acid Area as a result of contaminant migration. Metals, VOCs, and SVOCs have not been detected in groundwater associated with the New Acid Area.

The human health evaluation indicates that PB concentrations in ditch surface soil and sediments at the Rocket Paste Area exceed the USEPA interim clean up range of 500 to 1000 ppm. Given current use, there are no estimated noncarcinogenic risks associated with exposure to ditch surface soil and sediments. Exposure of future residents to 24DNT, benzo(b)fluoranthene (BBFANT), chrysene (CHRY), and n-nitrosodimethylamine (NNDMEA) in Rocket Paste Area ditch surface soils produces an excess cancer risk of $2x10^{-4}$ which is slightly above the USEPA target range. Maximum PB levels of 10,000 ppm in Nitroglycerine Pond surface soils exceed the interim clean up level. However, there were no estimated noncarcinogenic risks associated with exposure to surface soil or sediments associated with the Nitroglycerine Pond.

Aquatic and semi-aquatic birds and mammals were found to be at risk from exposure to aluminum (AL), CU, and PB in the Rocket Paste Pond surface water.

Most terrestrial receptors including predatory species at the Rocket Paste Area are likely to be impacted by PB, 24DNT, and NNDPA in the ditch soils at the Rocket Paste Area. PB in the sediments at the Nitroglycerine Pond also present a risk to primary and secondary terrestrial consumers.

Oleum Plant, Oleum Plant Pond, and Ballistics Pond

At the Oleum Plant, Oleum Plant Pond, and Ballistics Pond, groundwater is recharged by infiltrating precipitation and surface pond water infiltrating through pond bottom sediments and the loess layer. Because the loess layer appears to be absent at the Oleum Plant, precipitation likely infiltrates in this area at a higher rate. Groundwater flow direction in these areas is complicated by relatively thin silt and clay layers as well as an irregular bedrock surface. Because of lower permeabilities, the thin silt layers and irregular bedrock surface tend to perch infiltrating water and groundwater, resulting in relatively steep water table gradients, particularly near the northern boundary of the BAAP facility. Because of these highly variable geologic conditions, groundwater flow velocities are also expected to be variable.

Subsurface soils and sediments at the Oleum Plant and Oleum Plant Pond contain concentrations of SO4 above background values that likely result from acid spills and leaks from the Oleum Plant and from the discharge of neutralized process and cooling water to the Oleum Plant Pond. SO4 was also detected above background values in groundwater beneath this site. No VOCs or SVOCs or metals were detected in groundwater samples collected at the Oleum Plant and Oleum Plant Pond.

Principal contaminants detected in sediments at the Ballistics Pond consisted of AL and SO4, consistent with the reported disposal of alum. In addition NIT was detected in pond sediments at background concentrations. No site-related VOCs or SVOCs were detected in the surface water or groundwater samples collected at the Ballistics Pond site.

At the Old Acid Area, SO4 was detected in subsurface soils associated with the acid production complex. The SO4 is likely a result of numerous spills and leaks during operations. No VOCs were detected in subsurface soils. PB and nickel (NI) were detected in near surface soils at concentrations above background concentrations, however the sporadic results do not suggest significant contamination of metals in soils at the Old Acid Area. There are no apparent impacts to groundwater quality from the Old Acid Area.

Noncarcinogenic risks associated with surface soils and sediments at the Oleum Plant and Oleum Plant Pond are below the USEPA target level. Concentrations of PB in soils at the Oleum Plant and Oleum Plant Pond do not exceed the USEPA interim clean up levels. There are no contaminants that are carcinogenic by the oral route. Neither carcinogenic nor noncarcinogenic risks exceed USEPA target levels at the Ballistics Pond. Concentrations of PB in Ballistic Pond sediments do not exceed the USEPA interim clean up level. In addition, no contaminants in groundwater associated with the Oleum Plant, Oleum Plant Pond, and Ballistics Pond exceed Wisconsin groundwater standards.

NIT and SO4 in Oleum Plant Pond sediments are the only contributors of ecological risk. The ecological evaluation of these contaminants in Oleum Plant Pond sediments indicates they are not likely to pose a threat to aquatic life due to the low Hazard Quotient (HQ) of NIT and low exposure point concentrations of SO4. Although elevated, concentrations of AL, ZN, ammonia (NH3), and PB in sediments and surface water at the Ballistics Pond are unlikely to pose a threat to aquatic receptors in this area due to low HQs for these constituents.

Old Acid Area and Old Fuel Oil Tank

Groundwater beneath the Old Acid Area and the Old Fuel Oil Tank flows generally southeast. Groundwater gradients in this area are relatively flat and flow velocities of 50 to 100 ft/yr were calculated. Although groundwater directly beneath these areas moves southeast, the regional groundwater system eventually forces groundwater originating at these sites to flow south.

At the Old Fuel Oil Tank site, SVOCs such as 2-methylnaphthalene (2MNAP), acenaphthene (ANAP), benzo(a)anthracene (BAANTR), benzo(g,h,i)perylene (BGHIPY), CHRY, fluoranthene (FANT), fluorene (FLRENE), and phenanthrene (PHANTR), all either related to fuel oil or fuel oil byproducts, were detected in shallow soils. However, most SVOCs were detected in soils less than 12 feet. No VOCs or SVOCs were detected in groundwater downgradient of the Old Fuel Oil Tank site, indicating that previous releases from this site are not impacting the groundwater. Elevated concentrations of chloride (CL) and SO4 above background were detected in one monitoring well, however, no source has been identified. A recent fuel oil spill approximately 200 feet southeast of the Old Fuel Oil Tank site is currently being addressed by the operating contractor, Olin Corporation.

The human health evaluations indicate carcinogenic and noncarcinogenic risks at the Old Acid Area and Old Fuel Tank are generally below acceptable target levels. However, concentrations of PB up to 1,500 ppm in surface soils at the Old Acid Area could pose potential risks to human health. Groundwater associated with the Old Acid Area and the Old Fuel Oil Tank does not pose a threat to human health. The ecological risk assessment models for the Old Fuel Oil Tank and Old Acid areas indicated that small mammals could be at risk from exposure to PB in surface soils. However, predatory species and larger mammals would likely not be a risk as they are unlikely to forage in these areas due to the lack of suitable habitats and frequent human activity in the Old Acid and Old Fuel Oil Tank areas.

The off-post area south of BAAP is extensively farmed. Soil borings and monitoring wells made and installed in this area encountered near-surface, fine-grained loess deposits underlain by approximately 200 to 220 feet of coarse-textured sands and gravels over weathered sandstone bedrock. Horizontal groundwater flow in the off post area south of BAAP is largely influenced by the water level (elevation 774 feet mean sea level [MSL]) in the Lake Wisconsin Reservoir north of the WP&L dam. This level is substantially higher than the water table elevation range in the adjacent sand and gravel aquifer. This head differential causes groundwater to flow south parallel to the reservoir until it discharges to the river below the WP&L dam. Groundwater flow velocities in this area range from 80 to 680 feet/year. The higher velocities reflect the steep gradients and converging flow lines associated with groundwater flow around the WP&L dam.

The groundwater sampling and analysis program of monitoring wells and private water supply wells south of BAAP identified a contaminant plume of CCL4, CHCL3, and TRCLE migrating south from BAAP. The highest concentrations of these compounds have been detected in samples from private irrigation wells. In addition, these compounds have been detected in samples from two well transects south of BAAP. Sampling and analysis of these wells has allowed characterizations of the lateral and vertical extent of the plume. Analyses of samples collected from the bedrock monitoring well located along county highway Z have not shown the presence of BAAP-related compounds, indicating that vertically the plume is located within the sand and gravel aquifer.

Four private wells were sampled to assess potential off-installation impacts of chemicals in groundwater at BAAP. No VOCs or SVOCs were detected in any of these four wells during the two RI sampling rounds. NIT and SO4 were detected in both sampling rounds in these wells. Neither of these analytes exceeded WESs. Although concentrations of NIT in the three wells did exceed the WPAL, detected NIT concentrations are within the estimated background range for groundwater and are likely a result of agricultural activities both off-post and at BAAP.

Because the RI data indicated that a VOC plume extends from the Propellant Burning Ground to the southern installation boundary, BAAP authorized Olin to perform additional off-post sampling of private domestic and irrigation wells south of BAAP with analysis for CCL4, TRCLE, and CHCL3. CCL4 was detected in three domestic supply wells and one irrigation well. Each of these wells draw water from the sand and gravel aquifer. No TRCLE was detected in any of the off-post wells sampled. CHCL3 was detected in 11 of 13 wells, generally at concentrations less than state and federal standards. No contamination was detected in off-post wells that draw water from the sandstone bedrock aquifer.

1.0 INTRODUCTION

This Remedial Investigation (RI) report (Data Item A011) for the Badger Army Ammunition Plant (BAAP) in Baraboo, Wisconsin (Figure 1-1), was prepared by ABB Environmental Services, Inc. (ABB-ES) as a component of Task Order 1 of Contract DAAA15-91-D-0008 with the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). This report presents results of the comprehensive RI program at BAAP. The RI activities were undertaken to meet federal permit conditions issued by the U.S. Environmental Protection Agency (USEPA) Region V (USEPA, 1988a), under authority of the Resource Conservation Recovery Act (RCRA), and requirements set forth by the Wisconsin Department of Natural Resources (WDNR) in the In-Field Conditions Report (WDNR, 1987) and modifications, February 1990, November 1991, March 1992, and October 1992 to the In-Field Conditions Report under authority of the Wisconsin Environmental Response and Repair Regulations; and Wisconsin solid/hazardous waste RCRA regulations (i.e., Wisconsin Administrative Code [WAC] Chapter NR-600). In addition, the RI activities were designed and conducted to meet the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) by USATHAMA under the National Contingency Plan (NCP) 40 CFR 30. The policies and goals of the National Environmental Policy Act (NEPA) were also considered and incorporated into the RI.

The RI Report is structured such that investigation details and findings are discussed on a site-by-site basis with some sites being grouped and discussed together where appropriate. Individual areas of investigation or groups of sites comprise each of the major Sections 6 through 11.

This organization of the RI Report allows the reader to focus on each individual site or groupings of sites from the description of site investigations through ecological risk assessments. Although this format creates some repetition from section to section; it allows the reader to have comprehensive RI data for a given site within each site-specific discussion.

USATHAMA acronyms and chemical codes are used in this report in describing results of chemical analyses. These acronyms and chemical codes are defined at the end of this RI report in the Glossary of Acronyms and Abbreviations and USATHAMA Chemical Codes. Within this report, concentrations of the various analytes of concern are referenced to background concentrations as measured in background surface soils, subsurface soils, sediments, and groundwater samples (Section 2) and Wisconsin Preventive Action Limits (WPALs) and Wisconsin Enforcement Standards (WESs).

Previous investigations by Ayres Associates (Ayres), Eder Associates Consulting Engineers (Eder), Envirodyne Engineers, Inc. (EEI), Foth & Van Dyke Industrial, Inc. (Foth & Van Dyke), Olin Corporation (Olin), R.F. Sarko and Associates, Inc. (Sarko), Warzyn Engineering, Inc. (Warzyn), and others identified 11 potential hazardous waste sites requiring further investigation. Environmental data from these efforts were summarized in the Master Environmental Plan (MEP) prepared for BAAP by Argonne National Laboratory (Tsai, 1988). The MEP presented recommendations for RI activities, which were largely followed during initial RI activities. The 11 sites investigated by ABB-ES include the (1) Propellant Burning Ground, including Landfill 1, (2) Deterrent Burning Ground, (3) Existing Landfill, (4) Settling Ponds and Spoils Disposal Area, (5) Ballistics Pond, (6) Oleum Plant and Oleum Plant Pond, (7) Nitroglycerine Pond, (8) Rocket Paste Area, (9) New Acid Area, (10) Old Acid Area, and (11) Old Fuel Oil Tank. The general locations of these 11 sites at BAAP are presented in Figure 1-2.

Initial project plans and field activities were conducted under Task Orders 2 and 5 of Contract DAAA15-88-D-0006; results indicated additional field efforts were needed. These efforts with their associated plans were conducted under Task Order 1 of Contract DAAA15-91-D-0008. Field RI activities were conducted in accordance with ABB-ES' Sampling Design Plan (Data Item A004), which is supported by the Management Plan (Data Item A003), the Quality Control (QC) Plan (Data Item A006), and the Health and Safety Plan (HASP) (Data Item A009), and associated addenda.

1.1 PURPOSE

The BAAP RI is designed to (1) characterize the existence and extent of toxic or hazardous chemicals in surface soils and sediments at the Propellant Burning Ground, Settling Ponds and Spoils Disposal Area, Rocket Paste Area Pond and Ditches, Oleum Plant and Oleum Plant Pond, Nitroglycerine Pond, Ballistics Pond, and Old Acid Area; and subsurface soils in and near potential source areas at the Propellant Burning Ground, Final Creek, Deterrent Burning Ground, Oleum Plant and Oleum Plant Pond, Old Fuel Oil Tank, and Old Acid Area; (2) develop a characterization and understanding of the hydrogeologic setting and distribution of chemicals in environmental media at 11 sites; (3) evaluate pathways and rates of chemical migration; and (4) assess the potential impact on human and environmental receptors. Data generated by RI field investigation and related assessments form the basis for identifying the preliminary response objectives that will be used to formulate remediation alternatives in the Feasibility Study.

1.2 SCOPE

Based on previous environmental studies at BAAP, 11 potential hazardous waste sites were identified as Solid Waste Management Units (SWMUs) and ranked according to potential contributions of hazardous chemicals to the environment (see Figure 1-2). Ranked in descending priority, these sites are the Propellant Burning Ground (including Landfill 1), Deterrent Burning Ground, Existing Landfill, Settling Ponds and Spoils Disposal Area, Rocket Paste Area, Oleum Plant and Oleum Plant Pond, Nitroglycerine Pond, Old Acid Area, New Acid Area, and Ballistics Pond. USATHAMA added an 11th site, the Old Fuel Oil Tank, to the list in October 1989 after discovery of fuel-contaminated soils during excavation of a water line in the vicinity of the old fuel oil tank foundation. The RI field program at BAAP has consisted of on-post investigations at the 11 priority sites as well as off-post investigations in the area south of the Propellant Burning Ground. The following activities were included in these investigations:

- BAAP site reconnaissance and compilation and review of available site information, including data from previous studies, aerial photographs, and documents describing past and current site conditions
- soil vapor surveys at the Propellant Burning Ground and Deterrent Burning Ground using 245 passive soil vapor collectors
- remote sensing geophysics at the Propellant Burning Ground and Landfill 1 using ground-penetrating radar (GPR) and magnetometer surveys
- remote sensing geophysics at the Deterrent Burning Ground using terrain conductivity (TC) and GPR

- three deep background borings with collection and analysis of nine background subsurface soil samples and installation of three background monitoring wells
- collection and analysis of five background surface soil samples
- 28 deep soil borings and 18 shallow soil borings with an associated 278 subsurface soil samples and laboratory analysis from 10 of the BAAP sites
- collection and analysis of 196 surface soil and near-surface soil samples from the Propellant Burning Ground, Nitroglycerine Pond areas, and Rocket Paste Area,
- collection and analysis of six surface water and 16 sediment samples from the Nitroglycerine, Rocket Paste, and Ballistics Ponds
- collection and analysis of four sediment samples from the Oleum Plant Pond
- a borehole geophysical survey of seven existing and 23 new wells located at the Propellant Burning Ground, Landfill 1, Deterrent Burning Ground, and Existing Landfill
- 79 on-post monitoring well installations at 10 sites and 24 off-post monitoring well installations south of BAAP with associated well development
- two rounds of groundwater sampling and analysis (November - December 1991 and April-May 1992) including 103 new monitoring wells and 93 existing monitoring wells in addition to three private residential wells
- excavation and logging of eight test pits at the Propellant Burning Ground and collection of 16 subsurface soil samples for laboratory analysis

- instrumentation performance and evaluation of a 24-hour aquifer test, including installation of six piezometers
- a horizontal location and elevation survey of 103 new monitoring wells, 28 deep soil borings, and 18 shallow soil borings
- installation and elevation survey of a permanent benchmark and temporary stream gauge on the Lake Wisconsin Reservoir

Preparation of the RI Report consisted of characterizing hydrogeologic conditions and assessing chemical distribution, migration pathways, potential receptors, and potential effects of identified chemicals on human and animal receptors and the environment. An Interim Phase I Report was prepared in January 1990a E.C. Jordan Co. to summarize the initial findings. This RI Report supersedes this interim report and is a new/current assessment of conditions at BAAP.

1.3 SUMMARY OF OTHER FIELD INVESTIGATIONS

1.3.1 Summary of Previous Field Investigations

This subsection provides a chronology and overview of past investigations relating to the sites discussed in this RI Report. Reports describing previous investigations that are summarized in this subsection were provided by BAAP as part of the initial site reconnaissance. Boring logs for these reports are included in Appendix D. Geotechnical and chemical data in each individual report have been summarized within this RI Report. In many instances, such as in the development of geologic cross sections, previous data have been referenced and used to supplement the RI data. For clarity, Table 1-1 summarizes previous field investigations consisting of well installations, surface soil sampling, and borings completed before initiation of RI activities at BAAP. Figure 1-3 shows locations of new and previously installed monitoring wells. This figure is a large fold out figure and is contained in a pocket at the end of Section 1.

U.S. Army Corps of Engineers (USACE), Mobile District - 1979. Three monitoring wells at both the Existing Landfill (i.e., S1134, S1135, and S1136) and the Propellant Burning Ground (i.e., S1144, S1145, and S1146) were installed and water levels obtained to aid in determining groundwater flow conditions at these two sites.

Boring logs of these wells were not recoverable for evaluation and assessment in this RI Report.

Envirodyne Engineering, Inc., BAAP Contamination Survey - 1981 (EEI, 1981). From September 1979 through October 1980, EEI conducted a preliminary contamination survey of BAAP to determine whether certain sites were source areas for contamination to the environment. The survey consisted of a geotechnical investigation and sampling and analysis program. Part of the geotechnical investigation included installation of 33 groundwater monitoring wells (i.e., S1101 through S1133) distributed throughout BAAP and hydraulic testing of those wells. Monitoring wells were installed using mud rotary drilling techniques and were developed by surging with compressed air. The sampling program included collection of groundwater, surface water, sediment, surface soil, and biological samples. These investigations focused on the Ballistics Pond, Oleum Plant and Oleum Plant Pond, Existing Landfill, Deterrent Burning Ground, Nitroglycerine Pond, Propellant Burning Ground, Rocket Paste Area, Final Creek and Settling Ponds, and Gruber's Grove Bay. These samples were analyzed by various techniques including atomic absorption spectrophotometry (AAS), automated colorimetric analysis, gas chromatography with electron capture detection (GC/ECD), and gas chromatography/mass spectrometry (GC/MS). The principal analytes evaluated were volatile and semivolatile organic compounds (VOCs and SVOCs), metals, propellants, dinitrotoluenes (DNTs), diethylphthalate (DEP), di-n-butyl phthalate (DNBP), nitroglycerine (NG), and nitrocellulose (NC).

The purpose of the survey was to determine whether contaminants were migrating across the boundaries of BAAP and, if not, to determine the potential for contaminants to migrate in the future. Based on survey results, EEI concluded that no contaminants were currently migrating off site. Some contaminants (most notably NC) had migrated off-installation in the past and were still present in high (although not necessarily harmful) concentrations in the sediments of Lake Wisconsin's Gruber's Grove Bay. NC could have been decomposing to form ammonia, also present in high concentrations in the sediments.

Additional EEI conclusions were that groundwater contamination at BAAP appears to have resulted from operations at both burning grounds and at the existing sanitary landfill. Contaminated groundwater in the vicinity of the Existing Landfill was very close to the boundary of BAAP, and was moving toward that boundary.

Groundwater contamination in the vicinity of the Propellant Burning Ground consisted of chloroform (CHCL3) and carbon tetrachloride (CCL4).

U.S. Army Environmental Hygiene Agency (USAEHA), Phase 2 Hazardous Waste Management Study, Propellant Burning Ground - 1982 (Andrew, 1982). This investigation consisted of collecting 45 surface soil samples at the Propellant Burning Ground, including 18 from Pad 1, 16 from Pad 2, one each from the three refuse pits, two from the contaminated waste area, and six background samples. Samples were collected at depths ranging from zero to 18 inches. Samples were analyzed for the explosives cyclotetramethylenetetranitramine (HMX), cyclonite (RDX), trinitrotoluene (TNT), and DNTs as well as Extraction Procedure (EP) Toxicity metals. Samples were not analyzed for organic solvents. Results of analyses of these samples indicated that surface soils in the two burning pad areas, the contaminated waste area, and refuse pits were contaminated with varying concentrations of 2,4-dinitrotoluene (24DNT) and 2,6-dinitrotoluene (26DNT).

Warzyn, Geological and Soils Survey and Groundwater Monitoring Program - 1982. This investigation, performed by Warzyn under contract to Olin, focused on drilling 18 borings with associated soil sampling, and installing 36 monitoring wells at the Deterrent Burning Ground, Existing Landfill, Propellant Burning Ground, and a site for a proposed new landfill (Warzyn, 1982a). The Warzyn borings and wells are the "82" series (see Table 1-1). Monitoring wells were installed using mud rotary drilling techniques and were developed by surging with compressed air. Soil samples from the three sites were analyzed for various physical parameters. In addition, analytical testing was performed on soil samples obtained from the Deterrent Burning Ground and Propellant Burning Ground. Groundwater samples were collected from the installed wells and analyzed for various organic and inorganic parameters.

This study concluded that subsurface soil samples obtained from borings at the Deterrent Burning Ground and Propellant Burning Ground were contaminated with various organic and inorganic compounds. The primary contaminants found in subsurface soil at the Deterrent Burning Ground included phthalates (PHTHL), polynuclear aromatic hydrocarbons (PAHs), DNTs, n-nitrosodiphenylamine (NNDPA), nitrates (NO3), and nitrites (NO2). At the Propellant Burning Ground, Warzyn found PHTHL, various PAHs, sulfates (SO4), and NO3.

Samples obtained from the new wells indicated that groundwater directly down-gradient of the three sites was contaminated with various levels and types of organic and inorganic chemicals. At the Deterrent Burning Ground, groundwater contained those organic compounds found in the soil (i.e., PHTHL, PAHs, DNTs, and NNDPA), as well as benzene (C6H6), CHCL3, methylene chloride (CH2CL2), tetrachloroethylene (TCLEE), and toluene (MEC6H5). At the Propellant Burning Ground, C6H6, CCL4, trichloroethylene (TRCLE), CHCL3, CH2CL2, PHTHL, DNTs, SO4, and NO3 were found. At the Existing Landfill, identified contaminants were SO4 and NO3.

Sarko, Engineering Report Groundwater Monitoring Wells Synthetic Acid Plant Badger AAP, Baraboo, WI (Sarko, 1982). In response to WDNR Consent Order 2A-81-1212-A and a request from the Olin Corporation/BAAP, Sarko performed a subsurface exploration program in the area of an October 1987 acid spill near the synthetic acid manufacturing area (New Acid Area). The objective of the exploration program was to evaluate soil conditions and install groundwater monitoring wells near the new acid facility. Four mud rotary soil borings were made and four monitoring wells and three piezometers were installed in the borings NAN-81-01A, NAN-81-02B, NAN-81-03B, and NAN-81-04B. The borings encountered up to approximately 3 feet of disturbed soil underlain by up to 19 feet of brown silty clay soils. Soils below this consisted of outwash sands and gravels. Grain size analysis of selected soil samples was conducted. No analytical samples from either groundwater or soils were collected as part of this program.

Sarko, Establishment of Five Groundwater Monitoring Wells, Physical Analysis of Soil Samples, and Chemical Analysis of Groundwater Samples - 1983 (Sarko, 1983). This investigation consisted of installing five monitoring wells (i.e., S83-1147 through S83-1151), and subsequent collection and analyses of three rounds of groundwater samples from each well. Since the installation, well designations were changed to S1147 through S1151 for consistency with previously installed wells. Three wells were installed along the southern boundary of BAAP. The other two wells were located in the north-central and central portions of BAAP. All five monitoring wells were installed using mud rotary drilling techniques and developed by surging with compressed air. Groundwater samples from these wells were analyzed for various organics and inorganics. MEC6H5 was found at elevated concentrations in three of the five wells (i.e., S1147, S1148, and S1151).

Ayres, Near-surface Soils Investigations at BAAP - 1984 (Ayres, 1984). This investigation, undertaken by Ayres under contract to Olin, consisted of Shelby tube sampling and physical and chemical analyses of soils. Samples were collected from the ground surface to 3 feet below ground surface (bgs) in six general areas of BAAP. Areas sampled were the Oleum Plant Drainage and Pond, Ballistics Creek and Pond, Nitroglycerine Pond Area, Rocket Paste Area Drainage, Final Creek and Settling Ponds, and a Control Pond. The physical analyses performed on the samples included Atterberg limits and laboratory permeability testing.

Physical tests indicated that permeability values for near-surface soils ranged from a high of 10^{-3} centimeters per second (cm/sec) for a poorly graded sand, to a low of 10^{-8} cm/sec for a low-plasticity silt. Chemical analyses of the samples indicated that EP Toxicity leachate threshold levels were not exceeded. NC and the six organic compounds were found in near-surface soils in Final Creek and the Settling Ponds Area at various locations and concentrations.

Chemical analyses included test methods to determine concentrations of NC, NG, six organic compounds (i.e., 24DNT, 26DNT, DEP, DNBP, diphenylamine [DPA], and 2-nitrodiphenylamine) and the EP Toxicity leaching test for eight RCRA-regulated metals.

Results of the chemical analyses of soils and sediments indicate the following:

- Low levels of lead (PB) were detected in Ballistics Creek and Pond sediments; however, leach tests indicate that leachable PB does not pose a potentially serious problem.
- Organic compounds (i.e., DNTs, DNBP, and DEP) and smokeless powder grains were identified in sediments collected from Final Creek.
- Organic compounds DNBP and DNTs were detected in sediments from Settling Ponds 1, 2, 3, and 4. Various metals, particularly PB, also were detected in sediment samples from the ponds; however, negative EP Toxicity leachate analysis suggested migration is not a concern.
- No chemical parameters observed in the study were detected in the Nitroglycerine Ponds; however, soils in the overflow pond area were acidic.

- SO4 was detected at elevated concentrations in Oleum Plant Pond sediments.
- PB was detected at numerous locations in sediments collected from the Rocket Paste Area main drainage ditch.

USAEHA, Phase 4 Hazardous Waste Management Study - 1984 (Daubel, 1985). The overall scope of this study was to determine the environmental impacts of open burning/open detonation grounds at various U.S. Army installations. As part of this Phase 4 Hazardous Waste Management Study, the horizontal and vertical extent of soil contamination at the BAAP Propellant Burning Ground was characterized by drilling and sampling 15 soil borings to approximately 50 feet. Eleven borings were drilled in the Propellant Burning Ground racetrack area and four in the contaminated waste area. Seventy subsurface soil samples from these soil borings were collected and analyzed for explosives and related chemicals and EP Toxicity metals. In addition, 15 samples were analyzed for organic compounds. Based on data presented in the Phase 2 and Phase 4 investigations, USAEHA concluded that soil in the Propellant Burning Ground is contaminated by various concentrations and types of metals, explosives, and organic solvents.

USAEHA, Interim Report Geohydrologic Study No. 38-26-0504-86, BAAP - 1985 (USAEHA, 1985). This investigation consisted of installing 10 monitoring wells (85 series wells) and subsequent sampling to characterize groundwater flow direction and the extent of the contaminated groundwater plume at and downgradient of the Propellant Burning Ground. These monitoring wells were installed using mud rotary drilling techniques and were developed by surging with compressed air. This investigation and subsequent report concluded that the contaminated groundwater plume extended approximately 3,000 feet south of the Propellant Burning Ground and was approximately 1,400 feet wide. Additionally, the report indicated that groundwater contamination at this site primarily consisted of CCL4, CHCL3, and TRCLE. This investigation did not document the vertical extent of the plume; however, it recommended that an additional investigation be conducted to define its depth. Subsequent sampling and analyses of these and other wells by Olin confirmed the report's conclusions relative to groundwater contamination at the Propellant Burning Ground.

Foth & Van Dyke, Investigation Report for the Soil Sampling, Analysis, and Evaluation of the Settling Ponds Spoils Site at BAAP - 1985 (Foth & Van Dyke, 1985). Foth & Van Dyke's investigation consisted of collecting 40 Shelby tube samples, and physical and chemical analyses of soil from the top 3 feet of ground surface from five dredge spoils disposal areas. Physical testing of the samples included laboratory grain-size analysis, Atterberg limits, and permeability testing. Chemical analyses of the samples included EP Toxicity metals, various inorganics, priority pollutant organic compounds, pesticides and polychlorinated biphenyls (PCBs), NG, NC, colloidal protein, and total organic carbon (TOC). The following two conclusions were drawn from this investigation:

- sampled sludge soils do not exceed the maximum allowable concentrations for EP Toxicity tests for metals.
- several organic priority pollutant compounds (i.e., DPA, PHTHLs, and DNTs) and two non-priority pollutant compounds (i.e., NC and NG) were found in many samples.

Warzyn, Subsurface Investigation, BAAP - 1986 (Warzyn, 1986). This investigation, conducted by Warzyn under contract to Olin, consisted of installing three monitoring wells. A shallow and deep well pair (i.e., S1152A and S1152B) was installed at the Settling Ponds. The third well (S1153) was installed downgradient southeast of the Existing Landfill in a low area between the perimeter road and perimeter fence. The wells were installed in borings using mud rotary drilling techniques. Wells were constructed of 4-inch inside diameter (ID) Schedule 80 polyvinyl chloride (PVC) riser and screens with 0.010-inch slots.

U.S. Army Materiel Command (USAMC), Explosive Reactivity Testing Program, BAAP - 1986 (Daubel, 1986). This program was conducted by USAEHA and consisted of collecting 51 surface soil samples from various locations at BAAP and analyzing them for EP Toxicity metals and reactivity. Twenty-two of these samples were collected from the Propellant Burning Ground at the burning pads and contaminated waste areas. Seventeen samples were collected from the Settling Ponds and Spoils Disposal Area, and 12 samples were collected from the Rocket Paste Area drainage ditches. Analyses of soil samples collected from the Propellant Burning Ground indicated the presence of PB above the detection limit in five surface soil samples; tests for explosive reactivity were all negative. Results of analyses of sediment samples from Final Creek, the four Settling Ponds, and the Spoils Disposal

Area were all negative for reactivity and EP Toxicity. Analysis of sediment samples from Rocket Paste Area drainage ditches indicated that no samples were reactive. However, two sediment samples from the northern portion of the main drainage ditch were determined to be hazardous with respect to EP Toxicity leachable PB.

USACE - Waterways Experiment Station Geophysical Investigation, Existing Landfill, BAAP - 1988 (Whitten and Sjostrom, 1988). The purpose and objective of this investigation was to detect and assess migration of potential contaminant plumes from the Existing Landfill and the Deterrent Burning Ground using remote sensing geophysical techniques. These geophysical techniques included electromagnetic (EM) induction, vertical electrical resistivity soundings, and horizontal resistivity profiling surveys. The EM and resistivity tests could not positively confirm the presence of contaminated plumes in groundwater in the immediate vicinity of the Existing Landfill and Deterrent Burning Ground. However, the survey did locate five specific anomalies that could be associated with potential contaminant movement. Four anomalies appeared associated with the Existing Landfill, because each was located generally downgradient (i.e., south and southeast) of the landfill. A fifth anomaly was found downgradient (i.e., southeast) of the Deterrent Burning Ground.

Argonne National Laboratory Master Environmental Plan for Badger Army Ammunition Plant (Tsai et al., 1988). The geological, hydrogeological, and chemical data collected before 1988 were reviewed, summarized, and presented in the MEP for BAAP. The MEP, prepared for USATHAMA, identified past activities and chemicals found in soils and groundwater, and recommended additional investigations to quantify the extent of contamination. These recommendations were the basis of the RI activities conducted by ABB-ES for USATHAMA.

1.3.2 Summary of BAAP Quarterly Groundwater Monitoring Data.

Between January 1988 and March 1993, BAAP collected quarterly groundwater samples from the majority of monitoring wells at BAAP. In response to Item #10 of the In-Field Conditions Report (dated September 10, 1987) and Item #27 of the Plan Modification (dated October 30, 1992), both issued by the WDNR, BAAP contracted Mid-State Associates, Inc. (Mid-State) of Baraboo, WI to evaluate and summarize the quarterly groundwater monitoring data. In March 1993, Mid-State published a Draft Groundwater Narrative Historical Summary Report, which reviewed and summarized the BAAP quarterly data from groundwater samples collected between January 1988 and July 1992 (Mid-State, 1993). This report was reviewed by ABB-ES to assess the BAAP quarterly data relative to the RI data. ABB-ES also retrieved and reviewed similar and additional quarterly groundwater monitoring data from January 1988 through September 1992 from USATHAMA's Installation Restoration Data Management Information System (IRDMIS). ABB-ES has sorted the IRDMIS data by site ID, date, and exceedance of State of WESs and WPALs for comparison to data presented in this RI Report. Quarterly data retrieved from the IRDMIS included only those wells sampled by ABB-ES during the RI.

The Mid-State report and groundwater data pulled from the IRDMIS are used in this RI Report for comparison to RI data collected by ABB-ES. A summary comparison of BAAP quarterly data to the RI data is presented by site in the RI Report as part of the contamination assessment, specifically in the groundwater contamination or summary of contamination sections. The primary focus during assessment of the BAAP quarterly data has been on exceedances of Wisconsin Public Health Groundwater Quality Standards for all analytes, and exceedances of Public Welfare Groundwater Quality Standards for SO4. BAAP quarterly data has not been incorporated into the RI Report tables and human health and ecological risk assessments due to potential differences in quality control criteria used for the BAAP quarterly data and RI report data. It should be noted that the BAAP quarterly data identify the same principle site contaminants as the two rounds of RI data. Minor differences do occur in degree of contamination and frequency of detection.

1.4 SITE IDENTIFICATION/REGULATORY OVERSIGHT

BAAP is a large industrial facility encompassing approximately 7,354 acres. During previous investigations, 10 potentially hazardous waste disposal sites were identified as requiring further investigative efforts to fully characterize contamination. Because BAAP has RCRA status by virtue of its Part B permit and status under WAC, Chapter NR 181, these sites were designated as SWMUs for facility assessment and corrective actions.

Although designated as SWMUs, the 11 sites at BAAP are being investigated in an RI/Feasibility Study (FS) under the U.S. Army Installation Restoration Program (IRP). The RI/FS follows from the CERCLA guidance and is designed to comply with requirements for the RCRA Facility Investigation (RFI) and Corrective Measures Study (CMS).

1.5 REMEDIAL INVESTIGATION REPORT ORGANIZATION

This RI Report and appendices present the findings from RI activities conducted by ABB-ES from the winter of 1988 through the spring of 1992. It is structured in general accordance with the latest USEPA guidance promulgated in interim final form in October 1988 by the USEPA Office of Solid Waste and Emergency Response as Directive 9335.3-01 (USEPA, 1988b). The purpose of the directive was to incorporate requirements of the NCP as modified by the Superfund Amendments and Reauthorization Act (SARA) of 1986 for the conduct of the overall RI/FS process. This report is organized by geographically grouped sites or SWMUs and then subdivided by major topic area for description and characterization.

The following general information is provided to assist in clarifying the presentation of chemical data within the RI Report.

Acronyms. Acronyms and USATHAMA chemical codes are used throughout the text, tables, and figures of this report. A list of these acronyms is located at the end of the report.

Tables. Generally, two types of data tables, summary data tables and appendix data tables, exist within the report. The summary data tables within the report contain only samples that had detects of site related contaminants. The appendix data tables, Appendix K, contain all the results of all sampling and analysis and contain detects and nondetects. These appendix data tables were downloaded directly from USATHAMA's IRDMIS.

Units for Chemical Results. For consistency purposes, chemical data for soil and sediment media are generally referenced as $\mu g/g$. Occasionally some soil data or sediment data will be referenced as mg/kg, if it is from previous studies or reports. Units for groundwater sample and Toxicity Characteristic Leaching Procedure (TCLP) sample results are generally presented as $\mu g/\ell$.

Toxicity Characteristics Leaching Procedure. The TCLP is used to characterize materials as hazardous waste. It is designed to determine the mobility of organic and inorganic chemicals, based on the ability of a mild acid to leach certain chemicals from contaminated waste (or soil), especially their leaching to groundwater if the waste (or soil) were put in land-based units for disposal. TCLP analyses have replaced the Extraction Procedure Toxicity (EPTOX) analyses. EPTOX analyses were performed on surface and subsurface soil samples collected from the Settling Ponds by contractors in the 1980s. TCLP analyses were performed on various surface and subsurface soils collected by ABB-ES during the RI.

Flagging Codes. Some chemical distribution figures use qualified chemical data to represent chemical distribution at a site. Specific flagging codes are not shown in the figure with the data. Data presented in the summary tables and in the "Downloaded IRDMIS Data" Appendix K does include data with appropriate flagging codes.

Significant Figures. To be consistent with laboratory results, reported chemical data results are not rounded to a fixed number of significant figures. The data is reported with the same number of significant figures as reported by the analytical laboratory.

Risk Tables for Subsurface Soils. Some tables in the Ecological Risk Assessment sections summarize subsurface soil sample results to a depth of 15 feet per USEPA risk guidance. However, additional samples were collected for analysis depths deeper than 15 feet to determine potential impacts to the groundwater. Because of these additional and deeper samples there are apparent discrepancies between the number of samples considered in the risk assessments and contamination assessments.

This introduction (Section 1.0) provides a brief overview of the purposes, scope, and summaries of previous investigations. Existing background information for BAAP is extensive; therefore, background and historical information is summarized in Section 2.0 for clarity. Section 3.0 describes chemical-specific, location-specific, and action-specific Applicable or Relevant and Appropriate Requirements (ARARs) that apply or must be considered, in addition to risks in assessing the contamination status and/or need for remedial action. Although the current regulatory driving force for action falls under Wisconsin Hazardous Waste Storage, Treatment, and Disposal as well as Wisconsin Environmental Response and Repair regulations (WAC, 1988) and the USEPA Region V RCRA Part B Corrective Action Requirement (Part B Permit) rather than the NCP, SARA indicates that state and local laws concerning hazardous waste removal and remedial actions are still applicable to non-National Priorities List (NPL) sites at federal facilities. Therefore, the development of ARARs is required to identify the regulatory environment and provide guidance in selecting remedial responses.

Section 4.0 presents a human health evaluation including an overview and scope, general approach and methods, and a quantification of health risks from soil and sediment as well as a qualitative evaluation of groundwater quality.

Section 5.0 presents the baseline ecological assessment. This includes an assessment of exposure pathways, exposure levels, and toxicity for aquatic and terrestrial receptors.

Sections 6.0 through 11.0 present assessments of historical site practices, geology and hydrogeology, contamination assessments, human health assessments, and site-specific ecological assessments. Specific site groupings within these sections are as follows:

Section 6.0 - Propellant Burning Ground, Landfill No. 1 and Settling Ponds and Spoils Disposal Area
Section 7.0 - Deterrent Burning Ground, Existing Landfill, and Northeast area of BAAP
Section 8.0 - Nitroglycerine Pond, Rocket Paste Area, and New Acid Area
Section 9.0 - Oleum Plant, Oleum Plant Pond, and Ballistics Pond
Section 10.0 - Old Acid and Old Fuel Oil Tank Area
Section 11.0 - Off-Post Area South of BAAP

Section 12.0 presents a summary and conclusions of the Baseline Human Health and Ecological Risk Assessments

2.0 BACKGROUND

BAAP is a government-owned, contractor-operated (GOCO) military industrial installation currently on standby status. BAAP is a facility of the Armament Munitions and Chemical Command (AMC COM) and is part of the USAMC headquartered at Rock Island, Illinois. This section describes background information on the location, environmental setting, and operations history of BAAP.

2.1 LOCATION

BAAP is located in south-central Wisconsin, approximately 9 miles south of Baraboo and 30 miles northwest of Madison (see Figure 1-1). BAAP covers approximately 7,354 acres within Sumpter and Merrimac townships in Sauk County. The installation is bounded by U.S. Route 12 on the west, Devil's Lake State Park on the north, and farmland on the south and east. State Highway 78 and Lake Wisconsin define the southeastern boundary. Lake Wisconsin was formed approximately 75 years ago by the construction of a power dam on the Wisconsin River 1.5 miles downstream and south of the installation boundary in the town of Prairie du Sac.

2.2 ENVIRONMENTAL SETTING

This section describes the general environmental setting in and around BAAP and includes discussions of climate, physiography, geology and hydrogeology, land use and biotic communities, and basewide ecological resource areas.

2.2.1 Climate

The climate of Sauk County is continental. Because of its location in the interior of the American continent, climatic extremes with wide variability from year to year are typical. Winter temperatures in Baraboo (December through February) average 18.4°F; the average summer temperature (June through August) is 68°F. The record high and low temperatures recorded at Baraboo are 101 and -45°F, respectively (National Oceanic and Atmospheric Administration, 1985).

Precipitation for the Baraboo area averages 30.9 inches annually. Approximately 21 inches of rainfall (70 percent of the annual total) typically falls during the growing season (April through September). Thunderstorms are common during this period, especially in June and July. The one- and 10-year, predicted maximum 24-hour rainfall totals for Sauk County are 2.3 and 4.1 inches, respectively. Annual net precipitation is near zero; however, annual lake evaporation for the Sauk County area from 1956 through 1970 was 35 inches (National Oceanic and Atmospheric Administration, 1985).

The soil is typically frozen from early December until late March, with a frost penetration depth to 30 inches (Hellewell and Mattei, 1983). The average snowfall at Baraboo is 40.8 inches per season (November to April) (National Oceanic and Atmospheric Administration, 1985).

Prevailing winds in Sauk County are westerly in winter and southerly in summer, averaging 9 to 12 miles per hour. Highest windspeeds usually are recorded in March, April, and November (U.S. Department of Agriculture, 1980).

2.2.2 Physiography

BAAP is situated on the southern edge of the Baraboo Range, which consists of metamorphic quartzite rock of the Precambrian Period. Topography is defined by this upland region, as well as glacial features resulting from the advance of the Green Bay Lobe of the Cary Substage of the Wisconsin Stage glaciation approximately 12,000 years ago (U.S. Department of Agriculture, 1980). The Green Bay Lobe Glacier, which advanced from east to west, covered the eastern two-thirds of BAAP before retreating. The terminal moraine of the Wisconsin Stage glacier extends from north to south across the central portion of the ammunition plant as shown in Figure 2-1. Topography east of the terminal moraine is gently undulating to hilly with complex slopes and numerous depressions; the outwash plain west of the terminal moraine is nearly level to gently sloping. Surficial soils in most areas at BAAP consist of fine-grained sandy silts characterized as windblown loess deposits.

Generally, most precipitation falling on the BAAP site either evapotranspirates or infiltrates to the groundwater system through the sand and gravel. The overall direction of surface drainage at BAAP is to the south and is partially controlled by man-made ditches. However, in the northwest portion of the site, ditches convey runoff to Ballistics Creek, which flows west from BAAP to Otter Creek. Nineteen ponds are present on site although most are dry throughout much of the year. Many ponds are not drained by surface streams. Ponds that contain water throughout most of the year such as the Ballistics, Oleum, Nitroglycerine, and Rocket Paste ponds represent perched water caused by the accumulation of fine sediments in the bottom of each pond.

2.2.3 Geology and Hydrogeology

Unconsolidated deposits underlying BAAP consist predominantly of outwash sands and stratified outwash sand and gravel, with lesser amounts of interbedded glacial till. The glacial outwash and till deposits are underlain by sandstone formations of the upper Cambrian Dresbach Group, and Precambrian granites and rhyolites of the basement complex (U.S. Department of Agriculture, 1980).

Major aquifers are present in unconsolidated deposits and sandstone formations beneath BAAP. Both aquifers are unconfined; they are likely hydraulically connected beneath most of the installation. Where low-permeability till deposits or shalely interbeds are present on the bedrock surface, the sandstone aquifer may be under semiconfined conditions. The general direction of groundwater flow is south-southeast (Tsai et al., 1988).

Before construction of the Wisconsin Power and Light (WP&L) dam, shallow groundwater from the sand and gravel aquifer likely discharged into the Wisconsin River along the entire length of the river. The creation of Lake Wisconsin by damming the river has effectively prevented groundwater from discharging to the southern portion of the lake.

2.2.3.1 Geology. The geologic setting at BAAP is generally characterized by a thick sequence of unconsolidated soil units deposited in association with late Quaternary glacial advance and retreat. These unconsolidated soil units are underlain by sedimentary and metamorphic bedrock dating to the Cambrian and Precambrian periods.

At the ground surface across most of BAAP, a 5- to 10-foot-thick fine-grained clayey silt unit (i.e., loess) overlies glacially derived soil deposits. The loess, representing windblown soil, comes from soil material exposed along outwash valleys during and after glacial retreat. The loess is laterally extensive in this region and tends to become thicker toward the Mississippi River (i.e., to the west).

During late Wisconsin Stage glaciation, the Green Bay Lobe Glacier advanced across the site from east to west covering approximately the eastern two-thirds of BAAP. This marked the maximum glacial advance of the Green Bay Lobe and is represented by a terminal moraine ridge approximately 60 feet high (Figure 2-1), transecting BAAP from north to south (Alden, 1918; and Thwaites, 1958). This moraine, named the Johnstown Moraine, is laterally extensive in southern Wisconsin (Clayton, 1989). Beyond the terminal moraine to the west, a thick sequence of glacial outwash sand and gravel was deposited.

Till in the terminal moraine and ground moraines to the east consists of large volumes of undifferentiated diamictons, glacial till, and glaciofluvial and glaciolacustrine deposits. Diamicton is a nongenetic term describing a non-sorted or poorly sorted, nonlithified, geologic deposit. Generally, the diamictons appear to have been washed of their fines and, in the absence of well-defined stratification, are not easily differentiated. Glacial tills located east of the Johnstown Moraine are typically composed of silty sands belonging to the Horicon Formation (Mickelson, 1984). At many locations, the diamictons and Horicon Formation glacial tills are difficult to differentiate.

Glaciolacustrine sediments typically consist of well-defined silt and clay units as thick as 25 feet. Silt and clay units generally were observed in the northern portion of BAAP and appear to have separate origins east and west of the terminal moraine. There are three principal differences between the silt and clay units encountered east and west of the terminal moraine. First, the units west of the terminal moraine are generally thinner than 1 foot while those east of the terminal moraine are often thicker than 1 foot, ranging upward to 5 to 10 feet thick. Second, the units west of the terminal moraine occur at more variable elevations (i.e., ranging from 755 to 850 feet above mean sea level [MSL]) than those east of the moraine (i.e., ranging from 740 feet to 800 feet above MSL). Silt and clay units west of the moraine occur at lower elevations as a function of distance south of the Baraboo Hills (e.g., S1129, adjacent to the hills, contained silt and clay at 831 to 842 feet above MSL, while S1126, approximately 4,000 feet south of the hills, had silt and clay at 758 to 765 feet above MSL). Third, depositional conditions were apparently different west and east of the terminal moraine. In areas west of the moraine, outwash soils were probably deposited in a braided stream environment, while east of the moraine glacial till soils were apparently deposited where the ice melted.

Where silt and clay units occur at or just above the water table, an elevated water table occurs. This condition has resulted in a complex groundwater flow system in the vicinity of the Deterrent Burning Ground and Existing Landfill.

Unconsolidated glacial deposits thicken from north to south in the northern portion of BAAP. Along the northern site boundary, soil deposits are thin or absent and bedrock outcrops are common. However, the bedrock surface dips steeply toward the south and soil deposits quickly thicken to a maximum of approximately 250 feet. Figure 2-2 illustrates a regional bedrock contour plan for the BAAP region based on monitoring well and private water supply well logs. The figure indicates the bedrock surface drops approximately 150 to 200 feet across the northern third of BAAP. Across the southern two-thirds of BAAP, the bedrock surface appears quite flat.

Bedrock geology at BAAP is dominated by sandstones from the Eau Claire Formation of the Dresbach Group beneath most of the site, with quartzites from the Baraboo Formation and quartzite conglomerates along the northern boundary of the site (Hanson, 1970). The Baraboo Formation consists of a series of large hills rising approximately 500 feet above BAAP to the north. These hills represent the southern flank of the Baraboo Syncline and have quartzite bedding that dips to the north. A Precambrian quartzite conglomerate apron borders the base of the hills. Water supply reservoirs at the northern BAAP boundary are located just above the bedrock surface near this conglomerate.

South of the Baraboo Range, beneath the BAAP facility, the quartzite surface dips steeply to the south and is overlain unconformably by Cambrian Period sandstones of the Dresbach Group. The Eau Claire Formation, a member of the Dresbach Group, was encountered in several borings installed for water supply production wells at BAAP. The Eau Claire Formation is typically characterized as fine-to-medium sandstone with minor amounts of shale and dolomite.

2.2.3.2 Hydrogeology. The principle groundwater flow system beneath BAAP occurs in the unconsolidated overburden soils. This aquifer is unconfined, receiving recharge from infiltrating precipitation and discharging groundwater to the Wisconsin River south of the WP&L dam. Figure 2-3, a regional water table contour map for BAAP, indicates groundwater flows toward the southeast in the northwestern portion of the site and toward the south throughout much of the remainder of the site with some southwesterly flow near the Lake Wisconsin Reservoir along the eastern base boundary. Along the northern BAAP boundary, a complex hydrogeologic condition featuring water table and steep gradients exists. The gradient on the water table flattens substantially and the flow direction changes from southeasterly to southerly across the central and southern portion of BAAP with likely discharge to the Wisconsin River or flows south within the sand and gravel beneath the river south of the WP&L dam.

The overall water budget for precipitation falling at the site is dominated by evapotranspiration, which accounts for approximately two-thirds to three-fourths of the average 30 inches of precipitation in this area. Surface water runoff at BAAP is limited and much runoff that does occur collects in isolated depressions where it slowly evaporates during summer months. Recharge to the aquifer is limited by infiltration through the fine-grained loess unit blanketing the region. Estimates of recharge to the underlying aquifer were completed for both site-specific conditions and watershed or basin-wide conditions. Site-specific recharge estimates are based on the water balance analysis developed by Thornthwaite and Mather with modifications for personal computer applications, as well as conditions in Wisconsin (Thornthwaite and Mather, 1955; and Scharch, 1985). The water balance considers average monthly climatological conditions, along with near-surface soil stratigraphy, surface slope, and vegetative cover, to assess soil moisture storage conditions and estimate deep infiltration. The site-specific water balance estimate for this area indicates a recharge rate on the order of 5 to 7 inches per year in areas where the loess layer is present. Where the loess layer is absent and only fine-grained sands are present at ground surface, the infiltration rate estimate is increased to 7 to 9 inches per year.

The site-specific water balance compares well with recharge estimates based on low-flow discharge conditions in the lower Wisconsin River basin. Recharge conditions may be estimated from low-flow stream discharges. Low-flow conditions represent average groundwater discharge, which is equal to average groundwater recharge assuming no change in storage. Given this condition, the basin-wide low-flow stream discharge rate of 0.2 to 0.8 cubic feet per second per square mile of basin represents an average annual recharge rate of 3 to 11 inches per year (in/yr) (Hindall and Borman, 1974). This agrees well with the site-specific estimate of 5 to 9 in/yr of recharge. Appendix H includes a detailed analysis of recharge estimates.

In the northern portion of BAAP, infiltrating precipitation and groundwater discharge from bedrock could encounter fine-grained glaciolacustrine layers before reaching the water table. This condition results in formation of a locally elevated groundwater flow system in this area. The fine-grained glaciolacustrine soils appear to generate locally semi-confined conditions in the underlying aquifer. This assessment is based on the discontinuous nature of the glaciolacustrine unit, and the locally irregular groundwater elevations beneath the glaciolacustrine unit in comparison with the regional water table elevation. Downward vertical gradients are present across the unit.

The presence of fine-grained glaciolacustrine soils and higher elevations of the bedrock surface also appear responsible for the steeper gradients observed in the northwestern portion of BAAP, as indicated in Figure 2-2. In central and southern portions of BAAP, the glaciolacustrine layers are absent and the horizontal gradient across the water table is substantially reduced. This condition is reflected in the flattened surface of the water table (see Figure 2-3).

Groundwater flow across BAAP is influenced by the WP&L dam on the Wisconsin River, which creates the Lake Wisconsin Reservoir. This reservoir extends north of the dam along the southeastern BAAP boundary and has an approximate 40-foot head drop at the dam. The water level in the reservoir (approximately 774 feet MSL) is elevated above the water table over much of the southeastern portion of BAAP. This prevents expected groundwater discharge to the reservoir and creates the potential for seepage from the reservoir to recharge the groundwater in this area. The net result is groundwater flow parallel to the reservoir with discharge to or flow beneath the river south of the WP&L dam. These flow variations are illustrated in Figure 2-3. The influence of the reservoir on the groundwater flow system extends to the northeastern portion of BAAP. It appears that groundwater flow in the northeastern portion of BAAP has a southeastern flow direction which slowly turns toward the southwest to flow parallel to the Lake Wisconsin Reservoir. It should be noted that if groundwater from the northeastern portion of BAAP discharged to Wiegand's Bay there would be no substantial impact to Wiegand's Bay of the surrounding area. Groundwater monitoring along the northeast BAAP boundary has shown minimal impact to groundwater quality from site related activities. SO4 is the only site related compound detected along the site boundary that appears attributable to site activities. However, the SO4 concentrations detected exceed the WPAL but do not exceed the WES. Further, SO4 is only regulated as a secondary or public welfare standard, not as a primary or public health standard. This condition is discussed in more detail in Section 7.0.

Vertical groundwater flow gradients in the overburden aquifer beneath BAAP are generally small (Appendix H). However, upward vertical gradients from the underlying bedrock aquifer to the overburden aquifer appear to be significant. The potentiometric surface elevations in the bedrock aquifer within the BAAP area are between 800 and 900 feet above MSL (U.S. Geological Survey [USGS], 1974). Maximum groundwater elevations measured in monitoring wells screened in the overburden aquifer in the northern portion of BAAP are on the order of 800 feet above mean sea level (Figure 2-3 and Section 9.0). Groundwater elevations measured in monitoring wells screened in the overburden aquifer in the southern portion of BAAP are on the order of 765 feet (Figure 2-3 and Section 6.0). This elevation difference indicates a significant upward gradient from the bedrock aquifer to the overburden aquifer, particularly in the southern portion of BAAP. The presence of these upward gradients is supported by water level data from regional water supply well logs (Appendix D).

The amount of flow from the bedrock to the overburden aquifer is limited by the presence of a relatively low permeability shale or siltstone interbedded within the sandstone bedrock.

Groundwater resources in the BAAP region are used for domestic and municipal water supply, cropland irrigation, and commercial/industrial production. Well installation logs for those wells on file with the Wisconsin Geologic and Natural History Survey and WDNR have been collected and are included in Appendix D. Figure 2-4 illustrates approximate locations of the wells and differentiates wells installed in the unconsolidated sediments from bedrock wells.

There are five groundwater wells on-post at BAAP. The designation of each well, location, and current use are summarized in Table 2-1. Approximate well locations are shown in Figure 2-5. PW-1 is the only well currently in use as a potable water source and is tested quarterly by BAAP per WDNR regulations. In addition, PW-4 is the only production well screen in the unconsolidated sand and gravel aquifer. Production wells PW-1, PW-2, PW-3, and PW-5 are constructed to extract water from the bedrock aquifer. Logs of these wells are provided in Appendix D.

2.2.4 Regional Groundwater Flow Model

A two-dimensional numerical groundwater flow model (Appendix J) was developed to simulate regional water table conditions in the unconsolidated sand and gravel aquifer underlying BAAP. The model was used to help evaluate the regional flow system, particularly the influence of the Wisconsin River and Lake Wisconsin Reservoir. This model and its results have been a tool in furthering the conceptual understanding of geologic and hydrogeologic conditions at the site. This discussion of the model presents the conceptual model setting, describes the model applied at BAAP, discusses assignment of model parameters, reviews calibration and sensitivity analyses, and summarizes the results. Appendix J presents detailed results of this regional modeling effort. Site-specific modeling at the Propellant Burning Ground (see Subsection 6.3.5) was based on this regional modeling effort.

Conceptual Setting. The modeling effort is based on a conceptual model of the geologic/hydrogeologic system that consists of an unconfined, isotropic aquifer under steady-state conditions. This aquifer occurs in a sequence of thick highly permeable, unconsolidated glacial deposits overlying and bounded by sandstone and quartzite bedrock units with a much lower permeability. The lower permeability of the bedrock units (particularly the interbedded shales and siltstones found in the sandstone) likely restricts significant groundwater movement between the bedrock and unconsolidated flow systems. Given this condition, the model has not included the bedrock units as part of the active aquifer. In addition, the elevated system is not modeled as its influence appears to be limited to the northeastern area of BAAP. The eastern portion of the modeled area is bounded by the Wisconsin River. The size of the river and the surrounding topography suggest it is a major groundwater discharge zone, and, therefore, represents a no-flow boundary for the modeled area. Therefore, nodes to the east of the river were made inactive.

The WP&L dam on the Wisconsin River has a significant influence on the groundwater flow system. Immediately north of the dam, the Lake Wisconsin Reservoir generally does not receive groundwater discharge because the elevation of the reservoir (approximately 774 feet above MSL) is above the water table elevation over much of the modeled area. The higher elevation of the reservoir results in a groundwater divide in the northeastern portion of BAAP. Groundwater to the northeastern portion of this area, with an elevation above 775 to 780 feet MSL, may flow east and discharge directly to the Lake Wisconsin Reservoir (likely at or above Wiegand's Bay), while groundwater in the southwestern portion of this area flows south before discharging to the Wisconsin River below the WP&L dam. The precise location of the groundwater divide is not well defined because of the very flat water table in this area, and could vary due to seasonal fluctuations in the water table.

Model Description. The USGS Modular Three-Dimensional Finite Difference Groundwater Flow Model Code (MODFLOW) was chosen for the BAAP regional groundwater flow model. MODFLOW was selected for application at this site because is has been widely used in geologic settings similar to BAAP. Furthermore, WDNR and USEPA have had favorable experience with this model in similar applications. MODELCAD (Geraghty and Miller, 1989), a graphical interface groundwater model preprocessor, was used to assemble data sets for input to MODFLOW.

For simulations at BAAP, the model has been applied to simulate two-dimensional horizontal unconfined flow in homogeneous isotropic sand and gravel aquifer. A layered model was not deemed necessary for regional aquifer simulations as groundwater flow was predominantly horizontal in the principle area of interest. Observed vertical gradients in the sand and gravel aquifer are orders of magnitude less than horizontal. The bedrock aquifer is assumed to have a negligible impact on the sand and gravel aquifer. This assumption has been highlighted in Subsection 2.2.4. The assumption is reasonable as the hydraulic conductivity of the bedrock is lower than the overburden hydraulic conductivity. In addition, for the purposes of this modelling effort, hydraulic communication between the overburden and bedrock aquifer would be important if, there were downward flow from the overburden into the bedrock. However, well nest SWN-91-03 and production wells installed in the bedrock indicate either flat or upward gradients between the overburden and bedrock.

Assignment of Model Parameters. The finite difference grid designed for this model is composed of 37 rows and 24 columns with a variable grid spacing ranging from 1,000 to 2,000 feet. Figure 2-6 depicts the grid network, as well as assignment of boundary conditions.

The boundary conditions consist of no-flow conditions along the northern and part of the western boundary of the model area. Constant-head conditions were applied south of the WP&L dam along the southern model boundary. General-head boundary (GHB) conditions were applied in the northeastern area of the model to reflect the influence of Gallus Slough (see Figure 2-6), an embayment of the Lake Wisconsin Reservoir located just east of the active model area. The GHB acts similarly to a constant-head boundary although the surface water body being modeled (Gallus Slough) is located outside the modeled area. Streambed/groundwater interactive conditions were assumed at the eastern boundary of the model at the

Lake Wisconsin Reservoir above the WP&L dam. The functioning of this model module, the river module, is similar to the GHBs, although a streambed hydraulic conductivity is also included. The final boundary condition consists of a series of active variable head cells applied to the southernmost portion of the western model boundary where the sand and gravel aquifer is not bounded by the bedrock. These cells allow the water table elevation to vary and respond similarly to cells within the central (active) portion of the model. Within the model code MODFLOW is constructed to assign no-flow boundary conditions outside the active model area.

The aquifer was modeled with a hydraulic conductivity of from 150 to 200 feet per day (ft/day) (final calibrated value = 150 ft/day). This value agrees well with the results of the aquifer test conducted on extraction well BCW-3 (see Subsection 6.2.9). The aquifer bottom elevation based on the bedrock surface elevation is approximately 625 feet MSL in the central portion of the model area and slopes upward along the northern and western boundaries to elevation 775 and downward to elevations 600 to 575 along the southern boundary. Net recharge was assumed to consist of natural uniformly distributed infiltrating precipitation at a constant rate averaging 6 in/yr.

Model Calibration. *To simulate the steady state water table aquifer flow system,* the model was first calibrated to reflect known average conditions. This involved defining the modeled hydraulic parameters of the aquifer materials to match, as closely as possible, observed field conditions, and create a reasonable model of flow with respect to flow direction, gradient, and overall water mass balance. Steady state conditions for the water table aquifer were verified by reviewing water elevation data sets for 3/89, 10/89, 12/89, 6/90, 10/90, 12/91, 4/92 and 9/92. These data sets showed that while water level elevations in the aquifer varied by 2 to 3 feet over this time period the overall flow directions and gradients remained relatively stable reflecting an aquifer that is generally in equilibrium with steady state flow conditions.

After the boundary conditions were established and the model input was debugged, the BAAP model was calibrated by varying the hydraulic conductivity, streambed conductance, and recharge arrays. Following numerous calibration runs, where the hydraulic parameters were varied within reasonable limits to best represent observed site conditions, an adequate match between observed water table contours (see Figure 2-3) and modeled water table contours was achieved (Figure 2-7). As these figures indicate, the modeled water table is generally within 5 feet of the measured water table and flow directions and gradients are very similar.

Given the presence of a plume of VOCs emanating from the Propellant Burning Ground area and flowing south, it is important to establish the direction of groundwater flow south of BAAP. The modeling results indicate groundwater flowing south from the Propellant Burning Ground likely discharges to the Wisconsin River south of the WP&L dam, but north of the Village of Prairie du Sac Municipal Well (i.e., Well No. 2). A model simulation that included Well No. 2 pumping at 1,000 gallons per minute (gpm) did not indicate a measurable zone-of-influence. This likely reflects the large size of the cells in the regional model (500 feet by 500 feet in this area). This result suggests the Well No. 2 zone-of-influence is less than 500 feet. It should be noted that since this work was undertaken Well No. 2 has been rebuilt and now draws water from the bedrock aquifer rather than the modeled sand and gravel overburden aquifer. The mass balance of the regional model is good, indicating only 0.005 percent difference between input and output flows. Flows into the model were dominated by recharge (97.8%), uniformly distributed over the model, while flows out were dominated by discharge to constant head cells representing the Wisconsin River (94.1%). Minor flows in (2.2%) and out (1.2%) occurred at river cells representing the Lake Wisconsin Reservoir. Finally, minor flow out of the model also occurred at head dependent cells representing the Gallus Slough northeast of the model area. These results agree with the conceptual geologic and hydrogeologic setting discussed earlier.

Sensitivity Analysis. Following calibration, the BAAP model was subjected to a sensitivity analysis in which values of four model parameters were independently varied to determine the sensitivity of each parameter within the model. This analysis took the form of steady-state simulations in which hydraulic conductivity, recharge, aquifer bottom elevation, constant-head elevation, and streambed conductance were independently varied with five to six test values for each parameter.

The hydraulic conductivity/recharge ratio was the most sensitive parameter of those varied in the sensitivity analysis. The model was particularly sensitive to decreased values of hydraulic conductivity and increased values of recharge. The model demonstrated only moderate sensitivity to variation in the other model parameters. Overall, the sensitivity analysis indicated changes in hydraulic head which varied across the model with the parameter being tested. However, flow directions generally remained consistent. The major exception to this occurred during analysis of the stream bed conductance which indicated substantial groundwater flow out of the reservoir as conductance values were increased. As the hydraulic conductivity/recharge ratio was decreased the gradients across the site increased.

Summary. A two-dimensional numerical groundwater flow model of the BAAP region was developed and calibrated. The modeled water table elevations flow directions and gradients match well with water table elevations measured in the field. The modeled water table contours indicate that contaminated groundwater flowing south from the Propellant Burning Ground likely discharges to the Wisconsin River just south of the WP&L dam and north of the Village of Prairie du Sac Well No. 2. A more detailed description of this modeling effort is presented in Appendix J.

2.2.5 Background Analyte Concentrations

Background concentrations of various analytes including metals, anions, and indicator parameters in soils, sediments, and groundwater in the vicinity of BAAP were developed for use in the RI Report. Background concentrations in soils and sediments were estimated using selected soil samples collected from unimpacted areas of BAAP, soil background concentrations presented in the MEP, data collected by the USGS from sampling points in southern Wisconsin, data collected by WDNR from lakes and streams in southern Wisconsin, and data on U.S. soils (Kabata-Pendias and Pendias, 1984). Background concentrations in groundwater were determined by using data from selected wells located upgradient of suspected source areas at BAAP.

Between October 27 and November 7, 1991, Layne Environmental of Tempe, Arizona, under subcontract to ABB-ES, installed monitoring wells BGM-91-01, 02, and 03 (see Figure 2-8). Logs of the soil borings are included in Appendix D. Borings were advanced with 10-inch outside diameter (OD) dual-wall driven casing, utilizing air circulation for cuttings return. Table 2-2 summarizes the drilling procedures and monitoring well installations.

At depths of 20, 40, and 60 feet bgs, a 2-foot long, 3-inch ID split-spoon sampler was used to obtain subsurface soil samples. Drilling and sampling equipment was decontaminated between samples and borings by steam-cleaning with water from Production Well No. 2. Upon completion of each boring, a monitoring well was constructed in the borehole. Monitoring well materials consisted of flush-threaded, 4-inch ID Schedule 80 PVC. The PVC was supplied by Monoflex, Inc., of Largo, Florida. Well screen sections consist of Schedule 80 machine-slotted PVC with 0.01-inch-wide openings. Well screen lengths were 10 feet.

The wells have sandpacks placed in the annular spaces between the well screens and borehole walls or casings. The sandpacks generally extend 5 feet above the top of the screens. A 5-foot bentonite pellet seal was placed above the sandpack. Type II cement/bentonite grout was placed above the pellet seal and extended to the ground surface. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated approximately 3 to 4 feet into the ground. A coarse 1- to 1.5-inch diameter stone blanket (6 inches thick) was placed around each protective casing.

Well installation diagrams with associated boring logs are in Appendix D, which also contains the well construction and backfill material types and approval sheets. Grout was allowed to set for a minimum of 48 hours before the wells were developed with a submersible pump. Development included pumping of five well volumes plus any water added to the borings to control soil heaving during well installation.

2.2.5.1 Soils. Background analyte concentrations in BAAP soils were established using a combination of surface and subsurface soil samples collected from unimpacted areas of BAAP as well as surface soils data published by the USGS (Shacklette and Boerngen, 1984), and trace metals in soils and plants (Kabata-Pendias and Pendias, 1984).

2.2.5.1.1 Surface Soils

To better quantify background metals concentrations, five near-surface soil samples were collected on September 5 and 6, 1990, by ABB-ES and submitted for laboratory analysis of Target Analyte List (TAL) metals. The widely spaced sample locations, illustrated in Figure 2-8, were located in areas evaluated as having minimal disturbances from production activities at BAAP. Minor adjustments to the predetermined sample locations minimized potential for sample bias. Samples were located by pacing from known landmarks. Each sample was collected by excavating a 1- to 2-foot deep hole with a shovel. A stainless steel spatula was then used to transfer soil material to an 8-ounce prelabeled jar. Before use, the stainless steel spatulas were decontaminated with approved on-site water from Well No. 2, dried with paper towels, and stored in a plastic bag.

The samples represented near-surface soil conditions at BAAP and were described as dry, dark brown, fine sandy silt. These samples are appropriate for comparison with other near-surface soils. Table 2-3 summarizes the laboratory results and includes regional data. Overall, there is agreement between the BAAP samples and the regional data. However, the background zinc (ZN) concentrations in the BAAP samples are above the regional data while the background sodium (NA) concentration is below the regional data. The concentration of PB in the BAAP samples is within the range of regional data.

2.2.5.1.2 Subsurface Soils

To characterize the background subsurface soil conditions and to further develop the background chemistry of soils outside the 11 site areas, nine subsurface soil samples were collected from three background soil borings (three samples per boring). The soil borings, drilled as part of the background monitoring well installations, include BGM-91-01, BGM-91-02, and BGM-91-03. These borings were located near the northwestern BAAP boundary (see Figure 2-8).

The soil samples collected from the borings represent coarse-grained, outwash soils. The soil samples were analyzed for VOCs, base neutral and acid extractable organics (BN/As), nitrosamines (NAMs), DNTs, TAL metals, TCLP metals (cadmium [CD], chromium [CR], mercury [HG], PB); nitrite/nitrate-nonspecific (NIT), SO4, TOC, pH, and total petroleum hydrocarbons (TPHC). Table 2-4 presents detected analyte concentrations in the three borings. No VOCs, BN/As, NAMs, DNTs, or SO4 were detected in the nine samples. TPHC was detected in BGM-91-02 at depths of 22 feet and 62 feet bgs at concentrations of 6.24 and 27.3 micrograms per gram ($\mu g/g$). These low level results in conjunction with non-detects likely reflects the range of variability with the analytical method analysis. With few exceptions, the background subsurface data is in general agreement with the regional background data. Calcium (CA) and magnesium (MG) concentrations in the deep boring samples are generally higher than those of the regional concentration range while the background barium (BA), potassium (K), NA, and ZN concentrations are lower than the regional concentration range.

TCLP tests were conducted to assess the leaching or migration potential for CD, CR, HG, and PB in soils near selected priority sites. These analyses were also conducted on background samples to determine if soil considered as background would be characterized as hazardous waste because of toxicity characteristics. The results of the TCLP analysis are presented in Table 2-5.

HG was the only metal detected in the TCLP analyses. It was detected in the 22-foot sample from BGM-91-01 at a level above the certified reporting limit (CRL), but below the regulatory enforcement standard. No background subsurface soil samples had detectable concentrations of TCLP metals.

2.2.5.2 Groundwater. Water quality data from seven monitoring wells along the western and northern installation boundaries were used to evaluate background groundwater conditions. These wells, located outside the zones of known and suspected influence from the SWMUs and industrial disposal operations at BAAP, provide the best available representation of background groundwater quality conditions. Locations of the seven wells are shown in Figure 2-8. The wells were sampled and analyzed during both Round One (Fall 1991) and Round Two (Spring 1992) and were analyzed for VOCs, BN/As, TAL metals, NIT, chloride (CL), SO4, total hardness (HARD), alkalinity (ALK), and total dissolved solids (TDS). VOCs and BN/As were not detected in any background samples. Mean concentrations for the metals, anions, TDS, and the indicator water quality parameters (i.e., specific conductance, ALK, and HARD) were calculated based on results reported in the two rounds of groundwater sampling and analysis. The mean concentrations for individual wells were then used to produce an installation background mean concentration and concentration range. These concentrations are summarized in Table 2-6.

In many cases, metals were not detected above the USATHAMA-CRL. These values are addressed as described in Section 5.3.3 of the *Risk Assessment Guidance for Superfund* (USEPA, 1989a), which directs the use of half the certified reporting limits for calculating means for analytes if there is reason to believe they are present in the sample. The CRL may be used if there is reason to believe the chemical is present close to the certified reporting limit concentration. The following decisions were made while determining the background concentrations for samples with no detectable concentration of a given analyte. Analytes that were not detected in any samples from the seven wells are listed as less than the CRL, and one-half the CRL was used in calculating installation background averages; this includes aluminum (AL), CD, Copper (CU), HG, manganese (MN), nickel (NI), and PB. The other analytes in Table 2-6 were reported above the CRL in at least one sample. For these analytes, the CRL was used along with the positive values (i.e., above certified reporting limits) to calculate the installation background average and concentration range values.

The NIT background concentrations require further explanation. Arithmetic means for NIT from individual background wells vary from 350 to 10,000 micrograms per liter (μg/ℓ). The average concentration in four of the seven wells was greater than the WPAL of 2,000 μg/ℓ. The mean for one well met the WES of 10,000 μg/ℓ. The combined mean of all the wells was 3,700 μg/ℓ. These data indicate that background concentrations of NIT in groundwater in the vicinity of BAAP are greater than regulatory standards at some locations. The highest concentration is reported in well BGM-91-03, which is located in an area of crop farming. It is important to note that wells S1129, S1130, and S1131 are screened in bedrock. Concentrations reported for most trace metals in these bedrock wells are consistent with those wells screened in the sand and gravel aquifer. One exception is NIT, which was detected at noticeably lower concentrations in the bedrock wells. Wells S1129, S1130, and S1131 are located immediately downgradient of wooded hills that are not being farmed. The NIT results from these bedrock and overburden wells provide evidence that the regional aquifer has been affected by farming practices, and these practices are the primary causes for the presence of NIT at the reported background concentrations. Additional NIT results are presented in the individual site assessments, which support the concept that agricultural practices are responsible for most of the NIT reported in groundwater samples.

Additional wells other than those included in Table 2-6 are used in the assessment of specific sites that evaluate groundwater quality directly upgradient from two sites. These wells include ELM-89-05 for the Existing Landfill and PBM-89-11 for the Propellant Burning Ground. Evaluation of background water quality of samples collected from these wells is presented in Sections 6 and 7.

Review of the BAAP quarterly groundwater data through September 1992 from the background monitoring wells indicates conditions similar to those detected in the two rounds of groundwater sampling from the RI. The principal compound exceeding WPAL and WES in both the BAAP quarterly data and the two rounds of RI data was NIT.

2.2.5.3 Sediment. To characterize background sediment conditions at the various ponds at BAAP, selected data from the WDNR has been assessed and tabulated. The WDNR has collected trace metal sediment data from more than 40 lakes and ponds in Wisconsin as part of a study on HG levels in fish (WDNR, 1989). Table 2-7 summarizes metals concentrations in sediments for five of the lakes and ponds in the Wisconsin study. The five ponds selected are located in southern and western Wisconsin and share similar geologic environments with BAAP. General background sediment quality has also been assessed at the Control Pond (see Figure 2-8). Results of this assessment are summarized on Table 2-8 (Ayres, 1984).

2.2.5.4 Surface Water. To characterize background surface water trace metals conditions, data from the WDNR were reviewed. The data are preliminary and the WDNR is in the process of updating their sample methodology and analytical techniques. Results obtained using the new techniques suggest that background concentrations of trace metals at various surface water stations across the state have lower concentrations than previously measured. As the report is not finalized, the new data from the WDNR has not been tabulated for this report; however, general comparisons to the data are noted in this report.

2.2.6 Land Use and Biotic Communities

Overall land use at BAAP consists of production and administration facilities, magazine areas, and unimproved buffer and safety areas. The magazine and buffer/safety areas consist of woodland and open areas, and agricultural land (pasture and cropland). BAAP consists of 1,642 acres of plant facilities, 1,028 acres of woodland, 300 acres of wildlife areas, and 4,383 acres of agricultural land (Figure 2-9).

Production and administration facilities, as well as road and soil rights-of-way, consist of mowed, improved grounds. According to the Pest Management Plan, there are approximately 26 miles of railroad tracks, 34 miles of tramway, 120 miles of paved roadway, 35 miles of improved roadway, and 18 miles of security fencing within BAAP (Hellewell and Hartmann, 1987). These areas and the rights-of-way for electrical, steam, and hot water lines are kept mowed and maintained to provide access, minimize pest infestations, and control thistle and other weeds, as required by Wisconsin Department of Agriculture regulations.

The pasture and cropland, shown in Figure 2-9, consists of 11 private leases and land leased to the U.S. Department of Agriculture (USDA) Dairy Forage Research Unit. Currently, the agricultural land is used primarily for cattle grazing, and corn, soybean, alfalfa, and hay crop production. Research plots managed by USDA are shown in

Figure 2-9. These research land uses are consistent with historical land use and for experimental studies of natural prairie grasses. Historical aerial photographs indicate the area was farmed extensively before construction of BAAP in 1942. Development of the installation and buffer zones has led to an increase in woodland and wildlife habitat since the 1940s, which may support a more diverse terrestrial community than surrounding farmland. The Wisconsin region in which BAAP is located likely represents an ecotone between the tall grass prairie ecosystem and the northern extension of oak hickory woodland prior to disturbance. Southern Wisconsin has been farmed extensively and has been largely in pasture and cropland since the mid-19th century.

Natural surface drainage at BAAP is poorly developed. Historical aerial photographs do not show any defined streams draining BAAP prior to construction of the plant. Drainage swales located along the existing Nitroglycerine Pond and stream and the Settling Ponds drainages may have been seasonally wet, but were farmed during the growing season. The head of Gruber's Grove Bay on Lake Wisconsin, adjacent to the southeastern plant boundary, received surface drainage from BAAP during mobilization periods. Currently, the surface water or wetland features at BAAP consist of the storm water and process water drainage systems (i.e., the Nitroglycerine Pond, Rocket Paste Area pond and ditches), Final Creek and the four Settling Ponds, five small ponds located in pasture areas, the Oleum Plant Pond, and the Ballistics Pond. Of these ponds, the Ballistics Pond is the only pond that contains water on a year-round basis. The Ballistics Pond supports a biota population including warm-water game fish species; fishing is not permitted in this pond.

The small ponds in the pasture areas appear to represent low areas where slumping of finer-grained sediments has been reworked by cattle to form a moderately impermeable bottom. These systems are likely highly seasonal and are severely limited by cattle usage.

During mobilization, the Settling Ponds and the Oleum Plant Pond contained standing water. Currently, vegetation in these systems suggests reasonably moist conditions in which a mixture of wetland and upland grasses and herbs dominates the floral community.

Species lists of flora and fauna at BAAP are presented in the Environmental Assessment (Hellewell and Mattei, 1983) and are further described for individual sites in Sections 6.0 through 11.0. No state or federal threatened or endangered species are known to exist at BAAP. Limited hunting, trapping, and fishing are permitted at BAAP under controlled conditions. The primary species taken (listed by common name) include white-tailed deer, red fox, pheasant, squirrel, rabbit, raccoon, opossum, skunk, muskrat, mink, sunfish, and bass.

2.2.7 Basewide Ecological Resource Areas

This subsection discusses wetland and upland areas, wetland attributes and functions, floodplain areas, habitats of special concern, and endangered species found within and proximate to BAAP.

2.2.7.1 Identification of Wetland and Upland Areas. Wetlands were identified to comply with the substantive requirements of the Protection of Wetlands Executive Order 11990, and the Wisconsin Shoreline-Wetland Management and Protection Program (WAC, 1989 and E.C. Jordan Co., 1990b). Wisconsin Wetlands Inventory maps available from the WDNR were used to identify wetland resource areas within the study area (WDNR, 1978).

Wetlands are referred to by type, according to the classification system developed by the U.S. Fish & Wildlife Service (USF&WS) (Cowardin et al., 1979), as modified by the WDNR. This classification is based on a hierarchical approach designed to organize wetland and deep-water habitats by characteristics of water, substrate, and floral/faunal development. The highest order in the classification is Class, followed by Subclass. Hydrologic modifiers are used in the Wisconsin Wetlands Inventory to further characterize a system as either lacustrine, palustrine, or riverine.

The most prominent wetlands identified within BAAP include the Settling Ponds/Spoils Disposal Area adjacent to Gruber's Grove Bay (Figure 1-2). These wetlands are within the emergent/wet meadows Class, and are characterized by herbaceous plants that rise above the surface of the water or soil. The vegetation falls under the Subclass "persistent," indicating that the plant remains persist into the next growing season. These wetlands also have the hydrologic modifier "wet soil, palustrine," indicating the wetlands do not have surface water for prolonged periods. Typical "wet soil, palustrine" species include cattails and sedges.

Numerous unclassified wetlands smaller than 5 acres are scattered throughout the south-central and northeastern portions of BAAP, and two dammed artificial ponds (the Nitroglycerine Pond and Rocket Paste Pond) smaller than 5 acres lie within the central portion of the facility (see Figure 1-2).

The Ballistics Pond, located in the northwestern corner of the facility (see Figure 1-2), is classified as an "open water pond." The Subclass, which designates substrate type, is unclassified. This water body has the hydrologic modifier of "standing water, palustrine," indicating that surface water is present for most of the growing season.

A lacustrine wetland with free-floating and rooted aquatic macrophytes is located in Weigand's Bay, just outside the eastern boundary of BAAP (see Figure 1-2). Weigand's Bay is part of Lake Wisconsin, upstream of Gruber's Grove Bay on the Wisconsin River. This wetland falls within the "aquatic bed" Class, which includes plants growing entirely on or in a water body. Typical "free-floating and rooted aquatic macrophyte" (Subclass) species include pond lilies, duckweed, and surface algae. This wetland also has the hydrologic modifier of "standing water, lake" indicating a water body of 20 acres or more having a maximum depth of 6 feet or less.

The Wisconsin River is not classified as a wetland under the Wisconsin Wetlands Inventory; however, under the USF&WS classification system, the flowage would be categorized as "riverine." As a resource area, the Wisconsin River provides a valuable habitat for fish and wildlife. The floodplains and wetlands along the river are used by wildlife during migration as a staging area, as an overwinter habitat (for resident species), and as a breeding habitat. These areas also provide scenic value and recreation via hunting and fishing (WDNR, 1981).

BAAP occupies nearly 7,354 acres of rolling pasture and cropland; approximately 40 percent of the land is pasture interspersed with storage buildings, 20 percent is corn and alfalfa fields, 14 percent is in various forms of woody cover (woodlots are generally less than 20 acres), and 4 percent is old field. The remaining 22 percent of land is a mixture of industrial facilities and mowed, grassy areas (Herron, 1984). Figure 2-9 shows the areas classified as woodland, agricultural, and wildlife/open habitat.

Although surface water resources are limited, the plant is located in the "Mississippi Flyway" waterfowl migration route. Consequently, many bird species are expected to use portions of the BAAP site as feeding and resting areas during migration.

Studies show that BAAP supports a healthy herd of 250 to 400 white-tailed deer (Odocoileus virginianus borealis) (Wegner, 1985). A 6-foot cyclone fence around the plant limits deer migration, although some deer have been known to jump the fence (Herron, 1984). These deer rely heavily on both corn and alfalfa as food sources. In the midwest United States cultivated crops such as corn and soybeans represent generally 41 to 56 percent of foods eaten by white-tailed deer on agricultural ranges.

2.2.7.2 Wetland Attributes and Functions. An assessment of wetland functional attributes was conducted to determine, qualitatively, the value of the wetlands identified in the study area. Wetland functional attributes may include any or all of the following (USEPA, 1985a):

- maintenance of water supply (public and private)
- protection of groundwater supply
- control of flood and storm hazards
- maintenance of water quality standards and natural pollution abatement
- conservation and long-term productivity of existing biota, habitat diversity and stability, and hydrologic unity
- conservation and long-term productivity of fish, wildlife, timber, and food resources
- recreational, scientific, and cultural uses

The functional assessment is based on the classification of wetlands according to the Wisconsin Wetlands Inventory. The wetland areas identified in the study area have the potential to provide numerous functional benefits such as those listed, except flood control and recreational and cultural uses. These functional benefits are enhanced due to the limited amount of aquatic habitat in the area. Wetlands associated with the Settling Ponds/Spoils Disposal Area do not normally contain standing water. However, the significant area involved suggests these wetlands could serve an important role in maintaining water quality and providing food resources to various animals.

Certain wetland and deep water habitat areas, no matter what the status, are not associated with specific functional benefits. For example, riverine systems do not routinely contribute to the abatement of pollution, control of flood and storm damage, or protection of groundwater supply due to a lack of buffering/filtering vegetation in the stream or river channel. Moreover, existing functional benefits may be compromised when habitat quality has been degraded through chemical contamination, eutrophication, or physical destruction (e.g., increased siltation resulting in hydrological modification). This possibility will be addressed in the ecological risk characterization for each site.

2.2.7.3 Floodplain Assessment. A floodplain assessment was conducted to comply with the substantive requirements of the Floodplain Management Executive Order 11988. Flood Insurance Rate maps from the Federal Emergency Management Agency (FEMA) were used to identify floodplains within the study area (FEMA, 1980).

No areas of BAAP fall within the 100-year floodplain boundary (see Figure 2-9). Floodplain areas closest to the facility occur near the southeastern corner of BAAP, primarily adjacent to Gruber's Grove Bay, and along the Wisconsin River. The floodplain forest community along the Wisconsin River is characterized by silver maple, cottonwoods, and river birch. Green ash, white ash, black ash, and American elm increase in abundance in the shrub and canopy layers with distance from the river (WDNR, 1981).

Approximately 25 power dams are located on the Wisconsin River upstream (i.e., north) of BAAP. Water levels in some of the reservoirs are lowered in anticipation of spring runoff from snowmelt, and thereby provide some flood protection to downstream areas. Potential exists for a disastrous flood in some areas within the lower Wisconsin River Basin because of area topography and modification of the flow characteristics of the Wisconsin River (WDNR, 1981).

2.2.7.4 Habitats of Special Concern and Endangered Species. Pine Glen Natural Area, a 160-acre, state-significant, designated natural area is located along the northwestern boundary of BAAP in the southern flank of the Baraboo Hills. This natural area, located in Section 35 of T11N R6E, contains several natural communities, including southern and northern dry-mesic forest, southern dry forest, and cedar glade. Pine Glen also includes unusual erosional features and is designated as a National Natural Landmark (WDNR, 1989).

Otter Creek Bluffs Natural Area, a 1,300-acre, nondesignated natural area with a southern dry-mesic forest community, occurs just west of BAAP in Section 15 of T10N R6E (WDNR, 1989).

The peregrine falcon (Falco peregrinus anatum), a federal- and state-designated endangered bird species, has been recorded just west of BAAP in Section 15 of T10N R6E (WDNR, 1989). However, no federal- or state-designated endangered species were documented within the boundaries of BAAP.

2.3 HISTORY OF INDUSTRIAL OPERATIONS

The following general history of industrial operations at BAAP was taken from the Installation Assessment of Badger Army Ammunition Plant, Report No. 111, May 1977, by USATHAMA. Site-specific histories and an overview of past practices at each of the 11 SWMUs is described in subsequent site-specific sections.

The land required for the Badger Ordnance Works was procured by the government on March 1, 1942 and construction was started mid-year in 1942. A letter of intent was signed with Hercules Powder Company on November 10, 1941, authorizing it to initiate surveys and design the Wisconsin plant. The Hercules Powder Company was selected because it had successfully completed the construction of the Radford Ordnance Works near Radford, Virginia, and the Badger plant was to be a duplicate of the smokeless facilities at Radford. The plant was built by the Mason and Hanger Company of New York City.

BAAP production started in January 1943, and continued until September 1945, when the plant was placed on a standby status. During the operational period, BAAP employed 7,500 people and manufactured 271 million pounds of single and double base propellant.

On December 15, 1945, BAAP was declared surplus by the U.S. Government. In October 1946, the rocket facilities were withdrawn from surplus and placed in standby status. From 1945 to 1950, various portions of BAAP were in surplus, standby, and caretaker status and maintained by a small force of government employees. Over 4,189 acres were disposed of during this time, of which 2.2 acres went to the Kingston Cemetery Association, 2,264 to the Farm Credit Administration, and 1,922 to the War Assets Administration, bringing the total acreage available for BAAP operations to 6,380 acres.

During the early 1950s as a result of the plant reactivation for the Korean conflict, 1,173 acres were reacquired, bringing the total acreage to 7,553 acres.

Rehabilitation of BAAP by the Fegles Construction Company was completed in 1955 and the Liberty Powder Defense Corporation was contracted to operate BAAP. Through merger, the company today is known as the Olin Corporation. Total production during this period (1951 to 1957) was approximately 286 million pounds of single and double base propellant and employment peaked at 5,022 employees.

On March 1, 1958, BAAP was placed in inactive status. During this period, the land directly across from the main entrance on Route 12 was declared surplus and the acreage of BAAP was reduced to 7,417 acres.

The plant was reactivated effective December 23, 1965, with rehabilitation by Olin Corporation and various subcontractors. The propellants manufactured included ball propellant, smokeless propellant, and rocket propellant. Total production for this period was approximately 445 million pounds of single and double base propellant including 95 million pounds of ball propellant; 64 million pounds of rocket propellant; and 282 million pounds of smokeless powder. The plant at peak of production employed 5,390 people during this period.

On March 24, 1975, the Department of Defense ordered production operations at BAAP to cease upon completion of current orders and placed the installation in a standby status. This was the third such closure in the 50-year history of BAAP. Decontamination of facilities to the XXX condition was accomplished by the operating contractor, Olin Corporation, immediately upon completion of production operations and was completed in March 1977.

Since 1977, a new continuous process nitroglycerine plant has been constructed, proved, and placed in standby. Other facilities constructed include an ammonia oxidation plant, nitric/sulfuric acid concentrators, and a sulfuric acid recovery plant.

3.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121 of CERCLA requires conformance with ARARs of Federal and State regulations if a hazardous substance is to remain on-site as a result of remedial action.

CERCLA also requires that selected remedial actions are protective of human health and the environment. During the RI/FS, ARARs are employed in the development of remedial response objectives, remedial action alternatives, and site-specific cleanup goals. The determination of an alternative's protectiveness requires evaluation with respect to site-specific ARARs and risk factors. Acceptable exposure levels can then be determined through review and analysis of ARARs, if available, and risk factors, which evaluate systemic toxicants, carcinogens, and other factors related to exposure. ARARs can define cleanup goals when they set an acceptable risk level with respect to site-specific factors. Where ARARs do not exist or would not be sufficiently protective for the given circumstance, requirements to be considered (TBCs) and risk-assessment based data can be utilized to develop cleanup goals.

3.1 DEFINITION OF ARARS

Development of a comprehensive inventory of ARARs involves a two-tiered analysis: a determination of the applicability of an environmental regulation; and an evaluation of relevancy and appropriateness if the regulation is not applicable. A requirement may be either "applicable" or "relevant and appropriate," but not both.

An **applicable** requirement, as defined in Section 300.5 of the NCP, is a cleanup standard or other substantive requirement promulgated under federal or state environmental laws that *specifically* addresses the hazardous substance, the remedial action, the location, or other circumstance found at a CERCLA site. Only those state standards that have been identified by the state in a timely manner and that are more stringent than the applicable federal standard may be applicable.

A requirement that is **relevant and appropriate** for use as a cleanup standard at a CERCLA site is a cleanup standard or other substantive requirement that, while not "applicable" to a hazardous substance, remedial action, location or other circumstance found at the site, addresses problems or situations sufficiently similar to those found at the site that their use is well suited to the particular site. Only those state standards that have been identified by the state in a timely manner <u>and</u> that are more stringent than the applicable federal standard may be relevant and appropriate. To be used as a cleanup standard, a relevant and appropriate requirement must be found to be both relevant and appropriate.

In addition to the above criteria, TBCs, which are non-promulgated advisories or guidance issued by federal or state government, are not legally binding, and do not have status as potential ARARs, will be evaluated. In some circumstances, the TBCs will be considered along with ARARs and risk assessment results and may be used in developing the cleanup levels for individual sites. TBCs can be very useful in helping to evaluate what is protective at a site or how to carry out certain actions or requirements.

3.2 IDENTIFICATION OF ARARS

Requirements that govern actions at CERCLA sites, and which are therefore used to define the requirements for RCRA-directed SWMUs at BAAP, can be categorized into the three distinct areas listed below.

- **Chemical-specific requirements** are usually health- or risk-based standards that limit the concentration of a chemical found in, or discharged to, the environment. They govern the extent of site remediation by providing either actual cleanup levels, or the basis for calculating such levels. For example, groundwater standards can provide the necessary cleanup goals for the SWMUs with contaminated groundwater at BAAP. Chemical-specific ARARs for the SWMU may also be used to indicate acceptable levels of discharge in determining treatment and disposal requirements, and to assess the effectiveness of future remedial alternatives.

- **Location-specific requirements** govern special locations (e.g., wetlands, floodplains, and sensitive ecosystems) and man made features (e.g., landfills, disposal areas, and places of historical or archeological significance). These ARARs generally place restrictions on the concentrations of hazardous substances or the conduct of activities solely based on the site's particular location.

- **Action-specific requirements** involve performance, design, or other action-specific requirements and are generally technology- or activity-based. As remedial alternatives are developed, action-specific ARARs (pertaining to proposed SWMU remedies) provide a basis for assessing their feasibility and effectiveness.

Many regulations can fall into two or more categories. For example, many location-specific ARARs are also action-specific because they are triggered if remedial activities impact special locations. Likewise, many chemical-specific ARARs are also location-specific. For example, WAC Water Quality Standards for Wetlands (WAC, 1989) is both a location-specific ARAR because it pertains only to wetlands and a chemical-specific ARAR because it establishes a methodology for calculating cleanup levels for wetlands. Where a regulation has been determined to meet the definition of more than one category, the potential ARAR has been listed or discussed in the category judged most pertinent.

The identification of ARARs, along with other available non-promulgated advisory and guidance material, is an important component in the planning, evaluation, and selection of remedial actions during SWMU remediation planning. Individual ARARs should be identified at several points in the remedial response process. They must be identified on a site-specific basis, and therefore, as additional information is developed about the SWMU through ongoing RI/FS activities, the ARARs will be progressively refined.

Finally, CERCLA §121 provides that under certain circumstances an otherwise applicable or relevant and appropriate requirement may be waived. These waivers apply only to meeting ARARs with respect to remedial actions on site; other statutory requirements, such as that remedies be protective of human health and the environment, cannot be waived. If a waiver is required, this would be identified and discussed during the Detailed Analysis of Alternatives in the FS prepared for each specific SWMU.

3.3 APPLICABILITY OF REGULATORY REQUIREMENTS AT FEDERAL FACILITIES

Section 120 of CERCLA provides guidelines for remediation of hazardous constituents released from federal facilities. CERCLA requires that each department, agency, and instrumentality of the United States (i.e., federal facility), including the executive, legislative, and judicial branches of government, be subject to and comply with CERCLA, both procedurally and substantively, in the same manner and to the same extent as any nongovernmental entity. All guidelines, rules, regulations, and criteria carried out under CERCLA, including the NCP, are applicable to federal facilities. Therefore, like any other facility, federal facilities are subject to preliminary assessment, priority listing, and remedial action selection requirements. In addition, federal facilities must comply with the same cleanup standards, including federal and state ARARs.

Depending on the status of the federal facility (i.e., NPL site, non-NPL site, or RCRA facility), remedial action will be conducted under different authorities. Under Executive Order 12580 (i.e., Superfund Implementation), USEPA was delegated authority to govern the extent of remedies at federal facilities on the NPL. For federal facilities not listed on the NPL, the Secretary of Defense was delegated the authority to select remedial actions. Section 2701 of CERCLA (i.e., the Environmental Restoration Program) authorizes the Secretary of Defense to carry out a program of environmental restoration at facilities under his/her jurisdiction. Program activities must be carried out consistently with Section 120 of CERCLA, in consultations with the Administrator of the USEPA. State laws concerning hazardous waste removal and remedial actions are still applicable to non-NPL federal facilities by virtue of Section 120(a)(4) of CERCLA.

Because the facility is a RCRA-permitted hazardous waste management unit, RCRA regulations are applicable whether or not the facility is on the NPL. RCRA Section 3004 requires RCRA corrective action for all releases of hazardous waste constituents from any SWMU at a RCRA-permitted facility, regardless of when the waste was disposed of in the unit. Therefore, if there were a release of hazardous waste or constituents from a unit or activity located within the facility boundaries, regardless of whether the unit or activity was intended for treatment, storage, or disposal (TSD) of RCRA waste, site cleanup would come under the jurisdiction of the federal RCRA or state RCRA-authorized program. If the federal facility is a RCRA-regulated hazardous waste management unit, hazardous waste contamination within the facility boundaries is subject to RCRA corrective action authority. Because CERCLA has encompassed the concept of relevant and appropriate requirements, the resulting remedies are generally considered to be as or more protective of human health and the environment than RCRA Corrective Actions. Therefore, the decision to conduct the investigation and the subsequent remedies within the CERCLA framework may be considered a conservative approach to site remediation.

To date, BAAP has not been listed on the NPL. However, the site does operate a RCRA TSD facility licensed under a federal RCRA Part B Permit. This permit requires further investigation and/or corrective action at a number of SWMUs, including those addressed in this report. In addition, WDNR has issued an In-Field Conditions Report Approval that requires monitoring, investigations, and remedial action at the BAAP SWMUs being addressed.

3.4 CURRENT REGULATORY STATUS OF SOLID WASTE MANAGEMENT UNITS AT BAAP

As discussed in Subsection 3.3, the BAAP RCRA Permit requires further investigation and/or corrective action at a number of BAAP SWMUs. This Part B Permit was issued by USEPA on October 30, 1988. The RCRA license for BAAP contains both the USEPA permit conditions and state license conditions issued by Wisconsin's RCRA program. Wisconsin is authorized to administer the base RCRA program as well as some requirements of the Hazardous and Solid Waste Amendments (HSWA). Therefore, Part B Permit conditions, which are administered by USEPA, address HSWA requirements, including Corrective Action.

As part of the USEPA permit conditions a RFI and CMS program have been outlined. RFI requirements are being satisfied by the RI and the CMS requirements are being addressed by a FS. BAAP must also comply with the conditions of the WDNR In-Field Conditions Report Approval.

3.5 IDENTIFICATION OF LOCATION-SPECIFIC ARARS

As discussed in Subsection 3.3, federal facilities must comply with federal and state ARARs. Therefore, potential location-specific ARARs were identified based on a review of potential ARARs listed in the NCP preamble, WDNR regulations, and a review of BAAP potential special locations.

RCRA Subpart N and Wisconsin solid and hazardous waste management regulations (WAC, Chapters NR 504 - 516 and Chapters NR 600 - 685, respectively) play an important role where landfills and surface impoundments are identified as a site feature. Other regulations relevant to BAAP include the NEPA and the Clean Water Act (CWA) along with WDNR regulations governing surface water and wetlands. Remedial actions addressing contaminated sediments and surface waters should meet the requirements of these regulations. NEPA requires that federal agencies include in their decision-making processes appropriate and careful consideration of all environmental effects of proposed actions, avoid or minimize adverse effects of the proposed actions, and restore and enhance environmental quality as much as possible. An alternative located in a wetland or floodplain may not be selected unless a determination is made that no practicable alternative exists outside the wetland. If no practicable alternative exists, potential harm must be minimized and action taken to restore and preserve natural and beneficial value. Additionally, Section 404 of the CWA regulates discharge of dredged and fill materials to waters of the United States. Remedial actions within wetlands would require a 404 permit. These regulations along with Wisconsin Statutes Annotated, Chapter 30, Dredge and Fill Requirements, provide direction with respect to management of dredged materials.

The Clean Air Act (CAA) (40 CFR Part 52) defines requirements for a "major sources" of emissions. Emission limitations for major sources vary based upon the designation of the site as being within an "attainment" or a "non-attainment" area. Attainment areas are those regions of the country that are designated as being in compliance with the National Ambient Air Quality Standards (NAAQS) priority pollutants. Non-attainment areas are those parts of the country where compliance has not been attained for one or several criteria pollutants. The Sauk county, in which BAAP is located, is designated as an attainment area for all regulated air pollutants. Prevention of Significant Deterioration (PSD) requirements apply to attainment areas.

Because of the location of the facility within an attainment area, PSD regulations apply. The PSD regulations classify PSD areas as either Class I, Class II, or Class III. The classification of a particular area within a state is established within the State Implementation Plan (SIP) for CAA requirements. Sauk County, Wisconsin, is within the Southern Wisconsin Intrastate air quality control region. This region is designated as Class II for particulate matter, and Class II for all other regulated pollutants. Allowable PSD increments for each class are listed in Appendix A.

In addition, the Fish and Wildlife Coordination Act (16 USC 661 et seq.) requires that before issuing a federal permit or undertaking any federal action that causes the impoundment, diversion, or other control or modification of any body of water, the applicable federal agency must consult with (1) the appropriate state agency exercising jurisdictions over wildlife resources; (2) the USF&WS, and (3) the National Marine Fisheries Service. Under 40 CFR 6.302(f), reports and recommendations of wildlife agencies should be incorporated into environmental assessments. Table 3-1 is a checklist of the environmental setting and features of the 11 BAAP sites. Table 3-2 summarizes the potential location-specific ARARs for the features at each site. Synopses of the potential ARARs are presented in Appendix A.

3.6 Identification of Chemical-Specific ARARs

As discussed in Subsection 3.2, chemical-specific ARARs are usually health- or risk-based values that limit the concentration of a chemical found in or discharged to the environment. Federal regulations setting forth chemical-specific requirements for hazardous waste remediation include the Safe Drinking Water Act (SDWA), RCRA, HSWA, and the CWA. The State of Wisconsin also has promulgated a number of regulations that are parallel to, and in some cases are more stringent than, federal requirements. A brief summary of key chemical-specific ARARs issues is presented by environmental media in Table 3-3 which lists the identified ARARs by media. Specific standards and guidance values for chemicals identified at the site are tabulated in Table 3-4. A more complete discussion of the identified ARARs is in Appendix A.

Groundwater. Potential groundwater ARARs for conditions at, or stemming from activities at, BAAP include the SDWA, RCRA, and Wisconsin Drinking Water Rules (WAC, 1989) and Groundwater Quality Standards (WAC, 1990). The State of Wisconsin has proposed new Public Health Groundwater Quality Standards for the following compounds: barium (BA), vinyl chloride (CH2H3CL), benzene (C6H6), cadmium (CD), chromium (CR), 1,2-dichloroethane (12DCLE), toluene (MEC6H5), nitrite (NO2), nitrate (NO3), lead (PB), selenium (SE), and trichloroethylene (TRCLE) (Table 3-4). Groundwater data in this RI Report have been compared to current standards, but the impact of proposed standards should be evaluated prior to remedial action. The SDWA establishes both Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs). MCLs are enforceable standards that apply to specified contaminants that USEPA has determined to have an adverse effect on human health above certain levels. MCLs are set as close as feasible to MCLGs. (Feasibility in this determination takes both technology and cost considerations into account.) MCLGs are non-enforceable, health-based goals that have been established at levels at which no known or anticipated adverse effects on the health of persons occur and which will allow an adequate margin of safety. Because these values are based on no known or anticipated health effects, these values are considered to be protective of human health under nearly all circumstances. Under the NCP (40 CFR 300), MCLGs with values above zero that are established under the SDWA will generally be used as cleanup levels for groundwater that is a current or potential source of drinking water. This requirement is dependent upon an evaluation of the circumstances of the release.

In addition, federal nonpromulgated advisories or guidance must be considered when ARARs for specific contaminants are not available. The TBCs include USEPA Health advisories (HAS), USEPA Risk Reference Doses (RfDs), and USEPA Carcinogen Assessment Group (CAG) Carcinogen Slope Factors (CSFs). In addition, the USEPA developed two guidance documents for assessing risks and determining contaminant transport and fate. The Acceptable Intake - Subchronic (AIS) health assessment documents provide values developed for the RfDs and health effects assessments (HEAs) for noncarcinogenic compounds.

Surface Water. Surface water at BAAP is protected by federal and state regulations, including federal CWA Ambient Water Quality Criteria (AWQC), Wisconsin Water Quality Standards, and Wisconsin Water Pollution Control Regulations. Wisconsin regulations that govern surface water include:

- Chapter NR 102, Water Quality Standards for Wisconsin Surface Waters;
- Chapter NR 103, Water Quality Standards for Wetlands;
- Chapter NR 105, Surface Water Quality Criteria for Toxic Substances;
- Chapter NR 106, Procedures for Calculating Water Quality Based Effluent Limitations for Toxic Substances Discharged to Surface Waters; and
- Chapter NR 220, Water Pollution Control Regulations; Application for Discharge Permits.

Surface water cleanup goals should generally be attained at the point or points where the release enters the surface water.

Sediments. Regulatory values establishing acceptable concentrations of contaminants in sediments have not been promulgated by any regulatory authority. Acceptable concentrations of contaminants are determined on a site-specific basis by the governing regulatory authority.

Soil. At the federal level, there have been no specific, promulgated standards addressing acceptable soil contamination concentrations. Current methodology involves development of a cleanup level based on public health or ecological risk considerations. The USEPA has established interim soil cleanup levels for lead. The interim guidance recommends a cleanup level for total lead of 500 to 1,000 milligrams per kilogram (mg/kg). Site-specific conditions may warrant levels lower than 500 mg/kg, based on an exposure assessment.

The State of Wisconsin is in the process of developing soil remediation standards. Draft standards for benzene, toluene, ethylbenzene, and xylene (BTEX) and 1,2-dichloroethane were released in the spring of 1992. Wisconsin currently bases soil cleanup levels on demonstrations which show that soil contaminant levels would not be expected to impact the NR 140 groundwater standards.

Air. Site remediation activities must comply with applicable or relevant and appropriate federal and state air quality emission standards. The potential chemical-specific ARARs for air are listed in Table 3-3. An expanded discussion of each of these rules is provided in Appendix A.

Federal Requirements. The federal air emission standards include the NAAQS, (40 CFR Part 50); National Emission Standards for Hazardous Air Pollutants (NESHAPs), (40 CFR 61); and New Source Performance Standards, (40 CFR 60);

> National Ambient Air Quality Standards. The NAAQSs include both primary and secondary standards. The primary standards are intended to protect public health; secondary standards are set at levels to protect welfare, including wildlife, recreation, and economic values. NAAQS do not apply directly to source-specific emissions limitations. Instead, the State translates the emission limitations into source-specific limitations through SIPs. Upon

USEPA approval, the SIP becomes both Federally enforceable and a potential Federal ARAR. The SIP for Wisconsin is composed of the State air regulations, and is currently under review.

New Source Performance Standards. New Source Performance Standards (NSPSs) establish emission limits for a number of different pollutants for certain classes of new stationary sources. The list of pollutants includes limits for fluorides, sulfuric acid mist, and total reduced sulfur. These provisions are generally not applicable to cleanup actions. However, if a facility is a new source subject to a NSPS (such as an incinerator), the requirement may be applicable. If the pollutants emitted and the technology employed is similar to the pollutant and source category regulated, the NSPS may be considered relevant and appropriate.

National Emission Standards for Hazardous Air Pollutants. National Emission Standards for Hazardous Air Pollutants (NESHAPs) are particulate emission limits for pollutants according to source type (i.e., industrial categories) that emit the hazardous pollutant. NESHAPS have been promulgated for beryllium and mercury from specific sources. NESHAPS are not generally potential ARARs because the sites rarely contain a specific regulated source and the standards of control are intended for the specific type of source regulated and not all sources of that pollutant. Part of a NESHAP may be relevant and appropriate in instances where a regulated emission is produced by other than the regulated source.

Hazardous Air Pollutants. The Clean Air Act Amendments (CAAAs) of 1990 established the requirement to promulgate new source-specific emissions standards for sources of 189 listed hazardous air pollutants (HAPs). These standards must reflect the maximum achievable control technology (MACT) considering cost, energy requirements and other impacts. The tonnage of potential HAPs to be emitted in a year determine whether or not a source will be designated as a major source and will therefore be subject to the CAAA permitting requirements.

State Requirements. State chemical-specific air emissions standards are established by four regulations: (1) General and Portable Sources Air Pollution Control Rules; Ambient Air Quality Standards (Chapter NR 404); (2) Particulate and Sulfur Emissions Rules; Control of Particulate Emissions (Chapter NR 415); (3) Organic

Compound Emissions Rules (Chapter NR 419); and (4) Hazardous Air Pollutants Emissions Standards (Chapter NR 445).

The General and Portable Sources Air Pollution Control Rules. Ambient Air Quality Standards are comparable to the NAAQS primary and secondary ambient air quality standards. Standards are established for sulfur oxides, suspended particulates, carbon monoxide, ozone, nitrogen dioxide, lead, and particulate matter with an aerodynamic diameter less than or equal to a nominal concentrations of respirable dust particles (PM_{10}). The primary air standard is the level of air quality that provides protection for public health with an adequate margin of safety. The secondary air standard is the level of air quality that may be necessary to protect public welfare from unknown or anticipated adverse effects.

The Particulate and Sulfur Emissions Rules. Control of Particulate Emissions applies to all air contaminant sources and requires precautions to be taken to prevent particulate matter from becoming airborne. Examples of precautions include but are not limited to use of water or chemicals for control of dust, application of plastic covering on material stockpiles and surfaces which can create airborne dust, or covering or securing of materials likely to become airborne while being moved on public roads.

The Organic Compound Emissions Rules. Requires that reasonable precautions be taken when handling organic compounds to prevent spillage or escape or emission of organic compounds, solvents, or mixtures. In addition, no person may dispose of more than 5.7 liters of any liquid VOC waste, or any liquid, semi-solid, or solid waste materials containing more than 5.7 liters (1.5 gallons) of any VOC, in any one day from a facility in a manner that would permit evaporation into the ambient air during the ozone season. This includes but is not limited to the disposal of VOCs that must be removed from VOC control devices so as to maintain the devices at the required operating efficiency.

The Hazardous Air Pollutants Emissions Standards. Establish air contaminant emission concentrations as percentages of threshold limit values established by the American Conference of Governmental Industrial Hygienists. Emission standards are listed for each contaminant for 24- and 1-hour averaging periods. The standards may be applicable to remedial activities that involve treatment by a process which generates hazardous air contaminant emissions. Some emission rates which may be considered at BAAP are listed in Appendix A.

3.7 IDENTIFICATION OF ACTION-SPECIFIC ARARS.

Action-specific ARARs provide a basis for screening remedial technologies, developing remedial alternatives, and assessing the feasibility and effectiveness of each remedial alternative retained for detailed evaluation. Action-specific ARARs, unlike location- and chemical-specific ARARs, are usually technology- or activity-based limitations that direct how remedial actions are conducted. Table 3-5 summarizes the potential action-specific requirements associated with each of the remedial alternatives that may be considered at BAAP.

4.0 HUMAN HEALTH EVALUATION

4.1 OVERVIEW AND SCOPE

This section presents the methodology used to assess human health risk at the BAAP site. The purpose of the baseline risk assessment is to determine whether there is a risk to humans associated with activities which may take place on a site before any remedial action is instituted. Risk assessments were performed for 11 contaminated areas of BAAP: (1) Propellant Burning Ground (including Landfill 1), (2) Settling Ponds and Spoils Disposal Area, (3) Deterrent Burning Ground, (4) Existing Landfill, (5) Nitroglycerine Pond, (6) Rocket Paste Area, (7) New Acid Area, (8) Oleum Plant and Pond, (9) Ballistics Pond, (10) Old Acid Area, and (11) Old Fuel Oil Tank. This section describes the general approach, methods, and assumptions employed in the risk assessments, regarding identification of chemicals of potential concern, exposure assessment, toxicity assessment, and risk characterization. Risk assessments for the individual contaminated areas will be presented in subsequent sections of the RI/FS.

The evaluation of human health risks at BAAP was conducted according to current USEPA guidance. For exposure to on-site soils, sediments, and surface water, health risks were evaluated quantitatively using methods described in *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A and Part B)* (USEPA, 1989d and 1991a) and *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (USEPA, 1991b). Additional guidance documents are referenced as appropriate.

Because there are no current human exposures to contaminated groundwater at the site, groundwater was evaluated qualitatively by comparing contaminant concentration values with applicable state and federal regulations or guidelines on water quality. Detailed descriptions of the key elements of these evaluations are contained in the following subsections.

4.2 IDENTIFICATION OF COMPOUNDS OF POTENTIAL CONCERN

Compounds of potential concern are a subset of the chemicals detected in environmental samples of a particular medium at a hazardous waste site. Compounds of potential concern are those contaminants associated with site sources and releases and which pose a potential public health risk to exposed populations. The procedures to select compounds of potential concern for each of the areas at BAAP are consistent with the guidance and requirements in USEPA's Human Health Evaluation Manual (USEPA, 1989d).

All compounds detected at concentrations greater than the certified reporting limits were identified and evaluated as compounds of potential concern. Several criteria were used to exclude chemicals. Compounds that were not considered site-related were:

- Those identified as laboratory or sampling contaminants.
- Inorganics that were not detected at concentrations greater than naturally occurring site-specific or regional background concentrations.
- Those compounds which were detected in fewer than 5 percent of the samples of a single medium at a site. This criteria could be used only when 20 or more samples were collected.

In addition, site related chemicals essential to human nutrition and detected at a concentration that would result in a daily intake lower than an allowable daily intake are excluded. Section 1.0 of Appendix M presents a table which compares recommended daily intake with predicted daily intake based on the exposure parameters of the exposed group to support the exclusion of the inorganic nutrients.

The number and identity of contaminants varied among the 11 SWMUs, as did the media that were contaminated. Contamination was identified in surface soil, subsurface soil, sediment, surface water, and groundwater, depending on the SWMU. Compounds detected at each SWMU are evaluated in the "Nature and Extent of Contamination" sections that follow for the individual areas. Selection of compounds of potential concern for human health risk assessment is described in the "Human Health Evaluation" section and supported by tables in Appendix O for each SWMU. Each table lists, by media, compounds detected at least once, the frequency of detection, minimum and maximum values detected, whether the chemical was retained as a compound of potential concern, the rationale for excluding an individual chemical and the exposure point concentration for compounds selected as compounds of potential concern. Compounds selected for evaluation in the risk assessment and their respective exposure point concentrations are summarized in the sections addressing each SWMU.

4.3 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of exposure to site-related compounds of potential concern present at or migrating from the site. The exposure estimates are combined with chemical-specific dose-response information to characterize the potential risk to human receptors.

This exposure assessment was based on current USEPA methodology and guidance for conducting exposure assessments at CERCLA sites (USEPA 1989d, and 1991a,b). These documents provide standard exposure scenarios and default values for many exposure parameters and were used, as appropriate, in this exposure assessment. Values for site-specific exposure parameters were chosen, as necessary, using best professional judgment and knowledge of expected current and future land use at the LAAP site. Each exposure parameter is appropriately referenced.

This section provides a brief description of the land use at and around the BAAP site and a summary of the media-specific exposure pathways. Table 4-1 summarizes the generalized elements of the conceptual site model for human exposures to chemicals in surface soil, subsurface soil, surface water, and sediment at BAAP. The exposed populations reflect current and potential future land use at BAAP.

4.3.1 Land Use

The environmental setting for BAAP is described in Section 2.0 and includes information about site history, climate, geology, and land use. Current land use includes:

- mowed and maintained administrative and production areas and transportation and utility rights-of-way
- pastures for beef cattle
- cropland producing alfalfa and corn
- USDA research plots for studies of native prairie grasses
- woodland areas
- wetlands and ponds
- old field habitats

The industrial component of this installation has been on standby status since 1977. The base has not been scheduled for closure so future land use at BAAP will in all likelihood remain substantially the same as current use. It is possible that construction activities might occur at some time in the future; for example, building new foundations or installing utility or drainage lines.

4.3.2 Populations Exposed

At the present time, BAAP is fenced and access is strictly controlled. Therefore, under current land use conditions, the following populations are potentially exposed:

- grounds maintenance workers
- USDA research workers
- farmers
- hunters

Based on the assumption that BAAP will continue to be an ammunition plant, potentially exposed populations under future conditions could include those mentioned above as well as construction workers.

Each of these potentially exposed populations is described below.

Grounds maintenance workers are engaged mainly in mowing and upkeep of administrative and production areas, roads, and utility rights-of-way. Currently, the Propellant Burning Ground is the only SWMU which is mowed. It is mowed an average of twice a year with a total of 16 manhours required. It is possible that future activities at BAAP might require other SWMUs to be mowed and maintained to permit access or the like. Although this activity is unlikely to lead to extensive contact with bare soil, mowing may generate sufficient dust so that inhalation of contaminants as well as incidental ingestion and dermal contact may occur. Consequently, risks to this population from all three routes will be evaluated.

Research workers come on-site infrequently to visit USDA research plots and are not expected to visit any of the contaminated areas addressed in this evaluation. Consequently, this population will not be evaluated quantitatively.

Farmers could be exposed to soils during field tilling operations such as plowing, disk harrowing, cultivating, and harvesting. Farmers also come on-site twice a year when beef cattle are trucked into and removed from summer grazing areas. Under current land-use patterns, none of the contaminated areas are cropped or grazed. Areas of contaminated soil adjacent to pastures are fenced with barbed wire. Current farmers will not be evaluated. Farming is an unlikely future activity at most of the SWMUs due to physical characteristics such as small size, presence of woodlands, or wet areas. However, it is possible that some contaminated areas might be suitable for crops, so a hypothetical, future on-site farmer population will be evaluated for ingestion, dermal contact, and inhalation of particulates and vapors.

Deer hunters are present on site for a relatively short period during the fall deer hunting season. Although hunters could have contact with soil during this time, the magnitude of their exposure would be less than that of the grounds maintenance worker who would be exposed to the same media by the same exposure routes. Consumption of meat from deer that may have browsed in contaminated areas is a possible route of exposure since deer are not constrained by fences. To evaluate this possibility, a study was performed on tissue samples obtained from deer at BAAP to determine whether 24DNT or 26DNT was accumulating in deer tissue. The results indicated that no DNT compounds were accumulating to detectable levels in deer (Shugart, 1991). Consequently, deer hunters will not be evaluated.

Construction workers building foundations or installing or repairing utilities in the future could be exposed to soils from the surface to depths of 15 feet bgs. This activity would provide opportunity for ingestion and dermal contact, and disturb the soil to the extent that inhalation of vapors and particulates could become significant. This population will be evaluated.

Although considered extremely unlikely, a scenario consistent with recent guidance was developed to evaluate potential health risks under a future residential land use scenario. Hypothetical future residents would be exposed to surface soil if they lived on contaminated areas. Children living near contaminated areas could be exposed while playing in contaminated sediment or surface water. The residential scenario is based on long-term, repetitive contact with contaminated soil and is separated to reflect exposure of a young child and an adult. It is, therefore, more conservative than any of the scenarios described above. Although it is unlikely ever to become a reality, the residential scenario provides a useful estimate of the upper bound of risk associated with human exposures at these sites. Future adult and child residents will be evaluated for ingestion and dermal contact expressly to provide a comparison to the other scenarios evaluated. Hypothetical residential scenarios will not be used to develop remedial action objectives or preliminary remediation goals.

4.3.3 Exposure Pathways Selected

Based on land use and human activities on site, the following exposure pathways are selected for quantitative evaluation:

- Incidental ingestion of surface soil by current and future grounds maintenance workers, farmers, and future residents, for comparison.
- Dermal contact with surface soil by current and future grounds maintenance workers, farmers, and future residents, for comparison.
- Incidental ingestion of surface and subsurface soil by future construction workers excavating in the area.
- Dermal contact with surface and subsurface soil by future construction workers excavating in the area.
- Inhalation of dust and vapors by future farmers while tilling in contaminated areas.
- Inhalation of dust and vapors by current and future grounds maintenance workers.
- Inhalation of dust and vapors by future construction workers excavating in the area.
- Incidental ingestion of sediment by future child residents playing in the area.
- Dermal contact with sediment by future child residents playing in the area.
- Incidental ingestion of surface water by future child residents playing in the area.
- Dermal contact with surface water by future child residents playing in the area.

Not all these exposure scenarios are considered equally likely at all contaminated areas within BAAP. The exposure scenarios selected for each SWMU will be outlined at the beginning of the risk assessment section for each individual area in this document.

4.3.4 Quantification of Exposure

Exposure is defined as contact between a human and a chemical in the environment. The equations used to estimate chemical intake for each potential route of exposure are presented in Table 4-2. Specific values for exposure parameters for each exposed population are presented in Tables 4-3 through 4-5.

Contact with Surface Soil and/or Sediment. Exposure parameters for populations exposed to contaminated surface soil or sediment are outlined in Table 4-3.

Two values applied to all pathways are those for the soil adherence factor and the fraction ingested from a site. The adherence factor of 1.0 milligrams per square centimeter (mg/cm^2) suggested by USEPA in *Dermal Exposure Assessment: Principles and Application* (USEPA, 1992a) as a reasonable upper bound value is used. The fraction of soil ingested daily that comes from the site is conservatively estimated to be 100 percent.

The maintenance worker is involved primarily in mowing grass at various BAAP sites. The area mowed at each site is assumed to be the same, although it could be a ditch, an open meadow, or an area around a pond. It is assumed that a worker takes one day to mow each site and that each site is mowed weekly from mid-April to mid-October. This results in an exposure frequency of 24 days per year at each site. An inhalation rate of 2.5 cubic meters per hour (m^3/hour) for an exposure time of an 8-hour workday corresponds to the inhalation rate of 20 square meters (m^2) per workday recommended in USEPA guidance (USEPA, 1991b). The value for surface area exposed is the 50th percentile value for the combined area of hands and forearms in an adult (USEPA, 1990). The exposure duration of 25 years is based on the 95th percentile length of time an individual works at the same location (USEPA, 1991b). The remaining values are standard default factors suggested by USEPA in *Risk Assessment Guidance for Superfund, Volume I, Part A* (1989d) and in "Standard Default Exposure Factors" (USEPA, 1991b). This scenario will be evaluated using chronic RfDs.

If any contaminated areas are used for agricultural purposes in the future, the greatest human exposure would be associated with growing a seasonal crop such as corn or soybeans that requires cultivation during the growing season. The exposure frequency is therefore estimated to be three days per week for two weeks in the spring to prepare the soil, one day every two weeks through the summer for cultivation, and three days per week for two weeks harvest time in the fall. Because this hypothetical farmer is using heavy machinery on uncovered soil, a soil ingestion rate of 480 mg per day is assumed, based on USEPA (1991b) guidance on ingestion rates for construction or landscape workers. The surface area exposed is the 50th percentile value for hands and forearms (USEPA, 1990). Parameters for calculating inhalation intake include the inhalation rate and exposure time. The inhalation rate is taken to be 1.7 m^3/hour, based on the assumption that 50 percent of the time the farmer will be engaged in light activity with an inhalation rate of 0.8 m^3/hour and 50 percent will be moderate activity with an inhalation rate of 2.5 m^3/hour (USEPA, 1990). The time to plow or cultivate a 10-acre field is estimated to be one hour, assuming the tractor moves at 8 kilometers per hour (km/hour) and draws a tilling implement 5 meters wide. The exposure duration of 30 years (90th percentile of time lived at one residence, USEPA, 1991b) assumes the farmer tills the land for the duration of his residence there. The remaining values are standard default factors suggested by USEPA guidance (USEPA, 1989d, 1991b). This scenario will be evaluated using chronic RfDs.

Exposure to surface and subsurface soil to a depth of 15 feet bgs would be possible in the future during excavation or the installation and maintenance of underground utilities. A construction worker exposed during such activity is assumed to be working on site for four five-day workweeks, or a total of 20 days. Because this worker is exposed to uncovered soil, a soil ingestion rate of 480 mg per day is assumed, based on USEPA guidance (USEPA, 1991b). The surface area exposed is the 50th percentile value for the combined area of hands and forearms in an adult (USEPA, 1990). An inhalation rate of 2.5 m^3/hour for an 8-hour workday corresponds to and inhalation rate of 20 cubic meters (m^3) per workday recommended in USEPA guidance (USEPA, 1991b). Because this is a short-term exposure, the averaging time for noncarcinogenic effects is the 20-day exposure duration rather than a full year. This scenario will be evaluated using subchronic RfDs.

Hypothetical exposure of an older child to sediment is assumed to occur two days per week from mid-April to mid-October for a total of 50 days per year. The child is assumed to play on the site from ages 6 to 16 or a total of 11 years. The 50th percentile weight for this age group is 40 kilograms (kg) (USEPA, 1990). The surface area of exposed skin is based on the 50th percentile for hands, arms, feet, and legs. The remaining values are standard or default factors suggested by USEPA (1989d, 1991b). This scenario will be evaluated using chronic RfDs.

Table 4-4 outlines the exposure parameters for residential contact with surface soil in which the first six years of exposure are based on values for a 1-to-6-year-old child and the remaining 24 years on values from 7 years to 30 years old. The ingestion rate, body weight, exposure frequency and exposure duration are those presented by USEPA (1991b). The surface area exposed is the 50th percentile value for hands, feet, arms and legs of the child and hands and forearms of the adult (USEPA, 1990). This scenario will be evaluated using chronic RfDs.

Contact with Surface Water. Table 4-5 summarizes the exposure parameters for a 6 to 16 year old child swimming. This is assumed to be the same child exposed to the sediment. The surface area of skin exposed to the water is the 50th percentile value for total surface area for a child of that age group (USEPA, 1990). The body weight, similarly, is the 50th percentile value (USEPA, 1990). The remaining values are those suggested by USEPA (1989d). This scenario will be evaluated using chronic RfDs.

Relative Absorption Factors. Relative Absorption Factors (RAFs) may be applied to contaminant concentrations to adjust for the ability of the body to absorb the compound. For ingestion of contaminants adsorbed to soil particles or in water, an RAF of 1, implying 100 percent efficiency of absorption, is used as recommended by USEPA guidance (USEPA, 1989d).

For dermal exposure to soil, USEPA has recently reviewed percutaneous absorption in its document, *Dermal Exposure Assessment: Principles and Applications* (USEPA, 1992a) and identified a great many data gaps. Dermal RAFs have been developed for only a limited number of compounds. None of the compounds of potential concern at BAAP have RAFs. Further, USEPA has published no dose-response values for the dermal route. As a result, any approximation of dermal absorption would be associated with a high degree of uncertainty. Therefore, the dermal route of exposure to soil will not be quantified in any exposure scenarios and the calculation of risk will be underestimated to the degree to which dermal exposure would have contributed. Parameters for dermal exposure are given in the preceding descriptions to facilitate evaluation of the dermal route should dermal RAFs for soil exposure become available in the future.

Permeability Constant. For dermal contact with surface water, a permeability constant is applied to reflect the movement of the chemical through the skin. The chemicals of concern in surface water at BAAP are inorganics. USEPA, in *Dermal Exposure Assessment* (USEPA, 1992a), reports measured permeability constants for several inorganic compounds. These permeability constants are all specific to the individual compound rather than the pure inorganic and they are all equal to or less than the permeability constant of water. Therefore, the permeability of water provides a conservative estimate of the permeability of the inorganic compound and will be used as a default value. USEPA recommends a value of 1.55×10^{-3} centimeter per hour (cm/hr) as the permeability constant for water (USEPA, 1992a).

4.3.5 Derivation of Exposure Point Concentrations

This subsection describes the derivation of exposure point concentrations.

Soil, Sediment, and Surface Water. Monitoring data on chemical concentrations in soil and sediment samples are available for estimating exposure point concentrations. The media sampled and number of samples collected from each medium varies among the 11 sites. Exposure point concentrations for surface soil are based on data collected specifically to characterize surface soil, if available. In the absence of surface samples, data from zero to 2 feet bgs from soil borings is used. Exposure point concentrations used for exposure to subsurface soil include data from zero to 15 feet bgs. In many cases soil borings were not sampled specifically at 15 feet, so the sample taken from the depth closest to 15 feet bgs will be used instead. Specific information regarding data used will be provided in the discussion of each SWMU.

USEPA recommends the use of the 95 percent upper confidence limit on the arithmetic average as the exposure point concentration for normal or log normal distributions of data. However, statistical evaluation of the sample data indicate that the concentration data do not appear to conform to the Normal distribution. Log-transforming the data in an effort to "normalize" the data did not provide a significant improvement. Because the data (and the log-transformed data) were generally significantly divergent from the Normal Distribution, the 95th percentiles were estimated by nonparametric techniques. Nonparametric techniques are far less efficient than parametric techniques because they are limited to only the sample results, with no assumption as to the underlying distribution. Unfortunately probability plots and the Kolmogorov-Smirnov test for Normality indicated that, generally, this data set could not be assumed to be Normally distributed. Therefore, standard statistical procedures could not be used to estimate a 95 percent upper confidence limit. Instead, the following procedure was used to calculate a 95 percentile value.

Let the concentrations of a particular potential contaminant from a particular media (e.g. surface soil, subsurface soil, groundwater, ...) from n samples be, and let

$$X_1, X_2, \ldots, X_n$$

and let

$$X_{(1)} \leq X_{(2)} \leq \ldots \leq X_{(n)}$$

be the ordered values. Let m be the greatest integer less than or equal to

$$0.95 \dot{x} (n+1)$$

The estimate of the 95th percentile based on the order statistic is the value represented by the $X_{(m)}$. When there are fewer than 20 samples m=n, in other words, the maximum detected value. Otherwise, the m^{th} ordered value will be less than or equal to the maximum value.

Therefore, in the many cases where the number of samples taken is less than 20, the maximum detected concentration will be used for the exposure point concentration. In the instances where the sample size exceeded 20, the 95th percentile value, calculated as shown above, will be used as the exposure point concentration.

Chemical Concentrations in Airborne Particulates. One pathway by which humans could be exposed to site contaminants at BAAP is by inhalation of airborne dust particles resuspended as the result of farming activities (e.g., plowing, disk harrowing, cultivating, or harvesting), construction activities (e.g., excavation) or grounds maintenance activities (e.g., mowing lawns). PM_{10} from agricultural tilling are calculated by means of equations presented in Section 2.0 of Appendix M.

Concentrations of PM10 in air during excavation operations were set at a default of 150 micrograms per cubic meter ($\mu g/m^3$), which is the National Ambient Air Quality PM10 24-hour average. The concentrations (milligrams per cubic meter [mg/m^3]) of individual chemicals of potential concern were then obtained by multiplying the PM10 concentrations (converted to kilograms per cubic meter [kg/m^3]) by the concentrations of contaminants in soil (mg/kg) at each waste area considered for construction activities.

Emissions of respirable dust for grounds maintenance activities were estimated by applying a particulate emission factor (PEF) of 4.63×10^9 m^3/kg as developed in the Human Health Evaluation Manual (Part B), (USEPA, 1991a) and included as Section 3.0 of Appendix M. This is a conservative value for developing particulate concentrations inasmuch as it is based on disturbance of bare ground.

Volatilized Chemical Concentrations. Concentration of volatilized contaminants in air is estimated by applying a volatilization factor to the concentration of the contaminant in soil. Volatilization factors were developed only for compounds considered volatile and for which a CSF or inhalation reference concentration (RfC) was available. Compounds considered volatile are those with a Henry's Law Constant greater than 1×10^{-5} atm - m^3/mole and a molecular weight of less than 200 g/mole (USEPA, 1991a). The equation used to derive the soil-to-air volatilization factor is developed in *Risk Assessment Guidance for Superfund: Volume 1, Part B* (USEPA, 1991a). This equation and the volatilization factors derived for compounds of potential concern are presented in Section 4.0 of Appendix M.

4.4 TOXICITY ASSESSMENT

The toxicity assessment serves two functions: to provide information regarding the potential for a specific contaminant to cause adverse effects in humans, and to characterize the relationship between the dose of a chemical and the incidence of adverse health effects in the exposed population. The purpose of this assessment was to identify a dose-response value that can be used to evaluate quantitatively the potential health risks as a function of chemical exposure.

Toxicity assessments were conducted separately for carcinogenic and USEPA noncarcinogenic effects. USEPA has derived CSFs and RfDs to evaluate carcinogenic and noncarcinogenic risks, respectively. The definitions of CSFs and RfDs, as stated in USEPA (1989d) guidance are:

- Cancer Slope Factor - a plausible upper bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The CSF is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime exposure to a particular concentration of a potential carcinogen.

- Reference Dose - an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure concentration for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective from long-term exposure to a compound (as a Superfund program guideline, seven years to lifetime). Subchronic RfDs are intended to be protective from exposure over a portion of a lifetime (as a Superfund program guideline, two weeks to seven years).

Based on the definitions provided in the paragraph on Reference Dose, chronic exposures will be considered to be exposures lasting seven years or more. Subchronic exposures will be considered to last from two weeks to seven years. Appropriate reference doses will be used for each type of exposure.

Two sources of toxicity and dose-response information were used in this risk assessment: the Integrated Risk Information System (IRIS) and the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1992b and 1992c). IRIS contains descriptive and quantitative toxicity information and is considered to be the most authoritative source of verified USEPA dose-response values. IRIS is the preferred source for toxicity information, including CSFs and RfDs for supporting risk assessments (USEPA, 1989d). Information contained in IRIS supersedes all other sources of information, and only when information was not available in IRIS was the HEAST consulted. A copy of IRIS files available for compounds of potential concern as of August 1992 is presented in Appendix N. These files provide a summary of the pertinent toxicity information for each compound of potential concern.

The HEAST is prepared annually by USEPA's Environmental Criteria and Assessment Office with input from the Office of Solid Waste's Technical Assessment Branch. This document provides information on chemicals commonly found at both CERCLA and RCRA sites. HEAST summarizes interim slope factors and RfDs as well as additional toxicity information for specific chemicals.

The dose-response values for a comprehensive list of compounds of potential concern site-wide are presented in Tables 4-6 and 4-7 for oral noncarcinogenic and carcinogenic effects, respectively. These tables include the toxic effects, weight-of-evidence, uncertainty (both confidence level and uncertainty factors), and information about the type of study. The noncarcinogenic dose-response tables contain both chronic and subchronic RfDs. The chronic RfD will be used when the exposure duration exceeds seven years. The subchronic RfD will be used for the construction worker scenario, which assumes a 20 work-day exposure duration. Dose-response values for carcinogenic effects by the inhalation route are summarized in Table 4-8.

Dose-response values for noncarcinogenic effects by the inhalation route are no longer available. Instead, inhalation RfCs expressed in terms of concentration in air (mg/m^3) have replaced inhalation RfDs. Because of the complexities of inhalation toxicology, a measured air concentration was believed to be more accurate than an estimation of dose (USEPA, 1992c). RfCs are presented in Table 4-9.

Because dermal exposure to surface water is also of concern at this site, dermal toxicity values are also required. However, the USEPA has not yet established any dermal toxicity values. Until such values are developed, USEPA recommends the use of oral dose-response values (USEPA, 1992a).

To evaluate the risks associated with exposures to the PAHs detected at BAAP, surrogate dose-response values were assigned to PAH compounds without published values. The published CSF for benzo(a)pyrene (BAPYR) (7.3 [mg/kg-day]$^{-1}$) was applied to all other carcinogenic PAHs. The RfD for naphthalene (NAP) (4x10^{-2} mg/kg-day) was used for PAHs without RfDs.

A number of compounds of potential concern such as NC and NG detected at specific sites do not have published CSFs or RfDs. These compounds will be discussed quantitatively in the risk assessment section for the individual areas where they occur.

4.5 RISK CHARACTERIZATION

Risk characterization involves the integration of toxicity and exposure assessments into quantitative expressions of risk.

Carcinogenic risks were estimated by multiplying the estimated chemical intake for each carcinogen (in units of mg/kg-day) by its CSF (in units of (mg/kg-day)$^{-1}$). The result is a chemical-specific lifetime incremental cancer risk. This value represents the probability of developing cancer over a 70-year lifetime as a result of exposure to this chemical. Within each exposure pathway, cancer risks associated with multiple carcinogenic compounds were summed to yield a pathway-specific lifetime incremental cancer risk for a hypothetical individual within each potentially exposed population.

Cancer risks were summed independent of differences in target organ, weight-of-evidence for human carcinogenicity, or potential chemical interactions (e.g., antagonistic or synergistic effects). This assumption is consistent with USEPA's current approach to carcinogenic effects, which is to assume effects are additive unless adequate information to the contrary is available.

Noncarcinogenic hazards were estimated by dividing calculated chemical intakes for each noncarcinogen (in units of mg/kg-day) by the appropriate RfD (in units of mg/kg-day). The resulting ratio is termed the hazard quotient (HQ). HQs for individual compounds within an exposure pathway were summed to yield a hazard index (HI). As with cancer risks, hazard quotients were summed independent of the critical effect, target organ, or mechanism of action.

In the case of noncarcinogenic hazard by the inhalation route, the estimated air concentration of particulates or volatiles in mg/m^3 is divided by the RfC (in units of mg/m^3). Resulting HQs for individual compounds are summed to produce an HI.

The significance of risk estimates was evaluated by comparing risks to established target levels. USEPA has established target levels for the evaluation of carcinogenic risks and noncarcinogenic hazards at hazardous waste sites. USEPA's guidelines state that the total incremental carcinogenic risk for an individual resulting from multiple-pathway exposures at a Superfund site should not exceed a range of 10^{-6} to 10^{-4} (USEPA, 1989d). Therefore, risk characterizations in this report refer to carcinogenic risk estimates as being "below the target range" when risks are less than 10^{-6}; "within the target range" when risks are between 10^{-6} and 10^{-4}; and "above the target range" when risks are greater than 10^{-4}. The target hazard level for noncarcinogenic effects is an HI of 1 (USEPA, 1989d). Potential risks incurred by populations exposed to contaminants at BAAP are summarized in tables in the sections for each SWMU, while the risk calculation spreadsheets are presented in Appendix O.

Risk Characterization of Exposure to PB. USEPA has not published dose-response values for carcinogenic or noncarcinogenic effects of PB. Therefore, a quantitative expression of risk cannot be developed. However, there is an interim guidance document (USEPA, 1989c) establishing soil cleanup levels for PB of 500 to 1,000 parts per million (ppm). The range is designed to be protective of human health based on blood lead levels in children (a sensitive subpopulation) exposed to lead in a residential setting. Concentrations of PB detected at each SWMU were compared to the level set forth in this guidance to determine whether it poses a risk to human health.

Qualitative Evaluation of Groundwater Quality. Both Wisconsin and the federal government have developed health-based standards for contaminant levels in groundwater. Therefore, groundwater quality was evaluated qualitatively by comparison to these guidelines and standards. Contaminant concentrations in groundwater at each site were compared to four types of groundwater and drinking water guidelines and standards:

- USEPA MCLGs
- USEPA MCLs
- WESs
- WPALs

The USEPA Office of Drinking Water develops MCLGs based solely on a consideration of the potential adverse health effects of a chemical in drinking water. If a chemical is a carcinogen, the MCLG is always set at zero. An MCL is a legally enforceable standard set as close to the MCLG as possible, taking cost and technical limitations into account. The WESs are enforceable standards applicable to groundwater supplies in the state (WDNR, 1990). They do not apply to public water systems. WPALs are set at 10 percent of the WES for all substances that have carcinogenic, mutagenic, or teratogenic properties and at 20 percent of the WES for all other substances but are not enforceable standards.

Neither USEPA nor WDNR have promulgated standards for some of the compounds detected in groundwater at BAAP. Concentration levels protective of human health were calculated for these compounds based on exposure of an adult resident drinking 2 liters of water per day for 30 years. The equation and exposure assumptions are presented in Section 5.0 of Appendix M. The target levels were set at a risk level of $1x10^{-6}$ and an HI of 1. Detected concentrations of these compounds were compared to the calculated concentrations to determine whether the chemicals of concern (COC) might pose a risk to human health.

4.6 EVALUATION OF UNCERTAINTY AND CONSERVATISM

The interpretation of risk estimates is subject to a number of uncertainties as a result of the numerous conservative assumptions inherent in the risk assessment process. As such, risk estimates can most appropriately be viewed as upper-bound estimates of risk; actual risks may be substantially lower than those calculated through a quantitative risk assessment. Table 4-10 summarizes the most significant potential sources of uncertainty contained in the risk assessments and describes the likely tendency to over- or underestimate the quantification of carcinogenic and noncarcinogenic effects.

There are several categories of uncertainties associated with site-specific risk assessments. These include uncertainties related to the selection of contaminants of concern, toxicity assessment, exposure assessment, and risk characterization. Sources of site-specific uncertainty include the use of sampling data, selection of contaminants of concern, and assumptions regarding exposure.

There is considerable uncertainty regarding the likelihood of exposure to media of concern. Factors that would influence whether exposures occur include aesthetic factors such as the desirability of living or playing in an area, the presence of barriers such as fences or walls, and the presence of pavement and/or vegetation. Because it is difficult to determine the short- and long-term impact of these factors on exposure, it was assumed that potential exposure pathways were complete when, in fact, the likelihood for current or future exposure is uncertain.

The exposure scenarios also incorporate the conservative assumption that every instance of human contact with soil is with contaminated soil. The frequency of contact was not adjusted to account for the uncontaminated portions of the study areas.

The conservative assumption was made that no degradation of chemicals occurs over time. While it is extremely improbable that any of the compounds of potential concern are completely resistant to degradation, the chemical reactions that cause degradation are so complex that it is not feasible to obtain chemical-specific and site-specific degradation rates. Therefore, the assumption of no degradation was incorporated into the risk assessment, with the knowledge that it could result in an overestimation of actual exposure to chemicals of potential concern or an underestimate if degradation products are more potent carcinogens than the contaminant identified.

Because nearly all exposure parameter values applied in these risk assessments are default values established by the USEPA, rather than site-specific values, exposure scenarios represent upper-bound (conservative) exposure estimates. It is unlikely that long-term contact with soil will occur as assumed in these exposure scenarios.

Evaluation of the dermal pathway for exposure to soil or sediment depends on quantifying the amount of chemical absorbed through the skin. Data are available for few compounds, none of which are compounds of potential concern at BAAP. Because no compounds could be evaluated quantitatively, the risk contributed by dermal exposure to soil or sediment is unknown. Therefore, overall risk to a receptor is underestimated.

A significant source of uncertainty in the risk assessments is the use of chemical-specific toxicity values. Toxicity values based on human epidemiological studies frequently suffer from a lack of exposure data and any number of potential confounding factors, including concomitant exposure to multiple chemicals. For many chemicals, there is insufficient information on toxic effects in humans; consequently, data from studies of laboratory animals provide the basis for toxicity values. The practice of extrapolating effects observed in experimental animals to predict human toxic responses to chemicals is recognized as a major source of uncertainty in risk assessment. Further, for the dermal routes of exposure, oral toxicity values must be used by default because no specific values for dermal exposure are available. It is not known whether this results in an under- or overestimation of risk. For inhalation routes, toxicity values are not available for many compounds, resulting in an underestimation of risk.

Carcinogenic slope factors calculated by USEPA are based on the linearized Multi-stage (LMS) model, which assumes that risk can be extrapolated in a linear manner from the high doses used in animal bioassays to the low doses characteristic of human environmental exposures. These slope factors are considered to be plausible upper bounds of risk at the 95 percent upper confidence level. The accuracy of the risk at low doses predicted by the LMS model is unknown, but the risks at low levels of environmental exposure may be zero.

A high level of uncertainty exists with regard to the interaction of health effects of multiple chemicals. In the absence of evidence of synergistic or antagonistic effects of multiple carcinogens or noncarcinogens, the assumption was made that their effects are additive. This assumption, however, ignores dissimilarities in mechanisms of action, as well as potential synergistic and/or antagonistic effects. Furthermore, compounds may actually induce different toxic effects in different species or systems. Clearly, the assumption of additivity is simplistic; yet, at this time no reasonable alternative is available.

There are several sources of uncertainty specifically associated with noncarcinogenic health criteria. These include route-to-route extrapolation, identification of no observed adverse effect levels (NOAELs), use of subchronic studies to derive chronic health criteria, and differences in sensitivity among individuals in exposed populations. In an effort to compensate for these uncertainties in a health-protective manner, "safety" or modifying factors are applied by USEPA to the NOAELs selected for derivation of the RfD or RfC. Application of these uncertainty factors can be overly protective by several orders of magnitude.

In summary, because most of the assumptions employed in the analysis result in an overestimation of risk, the estimates calculated for BAAP can most appropriately be viewed as upper-bound estimates of risk; actual risks may be substantially lower than those calculated.

5.0 BASELINE ECOLOGICAL RISK ASSESSMENT

The purpose of the baseline ecological risk assessment at BAAP is to provide a screening-level evaluation of actual and potential risks that environmental contaminants pose to the resident and migratory fish and wildlife receptors using the site. This information, in conjunction with the human health risk assessment and other information presented in the RI Report, will be used to determine appropriate future action at each BAAP study area.

The objectives of the BAAP ecological risk assessment are to:

- characterize the existing ecological values and habitats at the site
- identify those ecological habitats that could be located within pathways of contamination
- identify the types of fish and wildlife receptors that would use those habitats which could be located within pathways of contamination
- evaluate the potential acute, chronic, and bioaccumulation effects expected from site contamination
- identify areas where further sampling may be needed (i.e., to identify data gaps)

The ecological risk assessment for the BAAP site includes the following elements:

- Selection of COCs (Subsection 5.1)
- Identification of Potential Ecological Receptors (Subsection 5.2)
- Ecological Exposure Assessment (Subsection 5.3)
- Ecotoxicity Assessment (Subsection 5.4)
- Ecological Risk Assessment (Subsection 5.5)
- Ecological Risk Assessment Uncertainties and Data Gaps (Subsection 5.6)

BAAP consists of 11 study areas within the confines of the 7,350-acre site. Subsections 5.1 through 5.6 of this ecological risk assessment provide general summaries of each of the ecological risk assessment elements, whereas Sections 7.0 through 10.0 provide specific details regarding environmental risk at each of the individual study areas.

Because the BAAP ecological risk assessment must meet the statutory requirements of both Wisconsin and federal regulations, this ecological risk assessment has been conducted in accordance with the following state and federal guidance documents:

- *Risk Assessment Guidance for Superfund (RAGS): Volume 2 - Environmental Evaluation Manual* (USEPA, 1989a)
- *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference* (USEPA, 1989b)
- Wisconsin Water Quality Standards (WAC, 1989)
- Wisconsin Shoreland-Wetland Management and Protection Programs (WAC, 1989)

Recent supplemental risk assessment guidance such as USEPA "Eco Update" bulletins (USEPA 1991b, 1992a, 1992b) have been incorporated into this ecological risk assessment, as appropriate.

5.1 SELECTION OF CHEMICALS OF CONCERN

The selection of COCs is a screening process used to define the chemicals requiring evaluation in the ecological risk assessment. Factors influencing the selection of COCs include: the validity of the data for ecological risk assessment; the classification of chemicals (e.g., inorganic, organic, pesticides); comparison of chemical concentrations with naturally occurring background concentrations (see Table 2-3) the physical and chemical properties of chemicals; the frequency of release and detection, and the inherent toxicity of exogenous chemicals (USEPA, 1989b). Contaminants were not selected as COCs if they were laboratory or sampling artifacts in accordance with USEPA guidance.

No plant roots, invertebrates, or vertebrate receptors at BAAP are likely to have significant exposure to either the groundwater or subsurface soil (>2 feet bgs) media at depths for which analytical data are available. Because significant exposure to subsurface soils or groundwater is not anticipated, quantitative data for these two media were not evaluated.

Media of ecological concern at BAAP are: (1) surface soil (<2 feet bgs) from all study areas, (2) surface water from the Nitroglycerine Pond, Ballistics Pond, and the Rocket Paste Pond, and (3) sediment from the Nitroglycerine Pond, Rocket Paste Pond, Oleum Plant Pond, and the Ballistics Pond.

5.2 IDENTIFICATION OF POTENTIAL ECOLOGICAL RECEPTORS

The purpose of the ecological characterization is to identify ecological receptors potentially exposed to contamination at BAAP. This subsection includes general descriptions of vegetative cover-types at BAAP, and is based upon a review of scientific literature and other published accounts, site-specific reports and records, contact with regional authorities, and observations made during ABB-ES site inspections. The presence or absence of any rare and endangered flora and fauna at the site, as well as information regarding any other critical ecological receptors, is reviewed in this subsection.

5.2.1 Land Use and Biotic Communities

The Wisconsin region in which BAAP is located could represent an ecotone between tall grass prairie and the northern extension of oak/hickory woodland prior to disturbance. Southern Wisconsin has been farmed extensively, and the region has been largely pasture and cropland since the mid-19th century.

Limited hunting and trapping are permitted at BAAP under controlled conditions. The primary species hunted and trapped include white-tailed deer (*Odocoileus virginianus*), red fox (*Vulpes vulpes*), ring-necked pheasant (*Phasianus colchicus*), gray squirrel (*Sciurus carolinensis*), eastern cottontail (*Sylvilagus floridanus*), raccoon (*Procyon lotor*), opossum (*Didelphis marsupialis*), striped skunk (*Mephitis mephitis*), muskrat (*Ondatra zibethica*), and mink (*Mustela vison*). Limited fishing for warm water gamefish is permitted in the Ballistics Pond.

Identification of Wetlands. Wetlands at BAAP were identified to comply with the substantive requirements of the Protection of Wetlands Executive Order 11990, and the Wisconsin Shoreline-Wetland Management and Protection Program (WAC, 1989 and E.C. Jordan Co., 1990b). Wisconsin Wetlands Inventory maps from the WDNR (WDNR, 1978) were used to identify wetland resource areas within the study area.

Wetlands were classified by type, according to the classification system developed by the USF&WS (Cowardin et al., 1979), as modified by the WDNR (1978). This classification employs a hierarchical approach designed to organize wetland and deepwater habitats by characteristics of hydrology, soils, and floral/faunal development. Hydrologic modifiers are used in the Wisconsin Wetlands Inventory (WDNR, 1978) to further characterize a system as either lacustrine, palustrine, or riverine.

The most prominent wetlands identified within BAAP include the Settling Ponds/ Spoils Disposal Area adjacent to Gruber's Grove Bay (see Figure 1-1). These wetlands are classified (WDNR, 1978) as emergent/wet meadow wetlands characterized by herbaceous plants that grow above the surface of the water or soil. These wetlands also have the hydrologic modifier "wet soil, palustrine," indicating the wetlands do not have surface water for prolonged periods. Typical species in emergent/wet meadow wetlands include cattails (*Typha latifolia*) and sedges (*Carex* sp.).

The Ballistics Pond, located in the northwestern corner of the facility (see Figure 1-2), is classified as an "open water pond"; this water body has the hydrologic modifier of "standing water, palustrine" indicating the presence of standing water for most of the growing season (WDNR, 1978). The approximately 5-acre pond reaches a maximum depth of 21.5 feet (Tsai et al., 1988).

A lacustrine wetland with free-floating and rooted aquatic macrophytes is located in Wiegand's Bay, just beyond the eastern boundary of BAAP. Typical species in this wetland include pond lilies (*Potamageton* sp.), duckweed (*Lemna minor*), and surface algae. This wetland also has the hydrologic modifier of "standing water, lake", indicating that it is a water body of 20 acres or more having a maximum depth of 6 feet or less.

The Wisconsin River is a riverine wetland under the USF&WS classification system (Cowardin et al., 1979). It flows in a southerly direction in the vicinity of the southeast corner of BAAP. The Wisconsin River provides valuable habitat favorable for fish and wildlife. The floodplain and wetlands along the river are used by migratory wildlife as a staging area, as an overwintering habitat, and as a breeding habitat (WDNR, 1981).

Numerous unclassified wetlands smaller than 5 acres are scattered throughout the south-central and northeastern portions of BAAP, and two dammed artificial ponds smaller than 5 acres lie within the central portion of the facility.

5.2.2 Flora

A list of plant species known to occur at BAAP is provided in Appendix P. Early successional-stage woodland and old-field herbaceous communities occur throughout BAAP. Wooded areas at Badger contain mixed secondary growth hardwoods. Species characteristic of upland hardwood forest noted at the site include white oak (*Quercus alba*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and hickories (*Carya* spp.). Scattered bigtooth aspen (*Populus grandidentata*), and cottonwood (*Populus deltoides*) are found in forested wetlands at BAAP.

Pasture land, old fields, and landfills at BAAP contain a number of secondary growth herbaceous species, including white clover (*Melilotus alba*), common milkweed (*Asclepias syriaca*), queen anne's lace (*Daucus carota*), plantain (*Plantago lanceolata*), thistle (*Cirsium vulgare*), chicory (*Cichorium intybus*), ragweeds (*Ambrosia artemiisifolia*), yellow vetchling (*Lathyrus pratensis*), clovers (*Trifolium spp., Melilotus spp.*), St. Johnswort (*Hypericum perforatum*), ox-eye daisy (*Chrysanthemum leucanthemum*), daisy fleabane (*Erigeron annuus*), burdock (*Arctium minus*), and a variety of grasses, including timothy grass (*Phleum arvense*), panic grass (*Panicum* sp.), and fescue grass (*Festuca* sp.). Many of the old field and pasture land tracts are mowed and maintained as a buffer zone around BAAP buildings.

Emergent wetlands at the site contain a number of species, including broad-leafed cattail (*Typha latifolia*), blue flag (*Iris versicolor*), various sedges (*Carex* spp.), common reed, soft rush (*Juncus effusus*), rushes (*Juncus* spp.), and bulrush (*Scirpus* sp.).

Additional information regarding vegetative cover types at the individual BAAP study areas can be found in the subsequent ecological characterization section for each study area (see Sections 6.0 through 10:0).

5.2.3 Fauna

Detailed lists of fish, birds, and mammals potentially occurring at and in the vicinity of the BAAP facility are presented in Table P-3 through P-5, respectively, in Appendix P. These lists were compiled from information provided in earlier documents, field guides, several published species accounts, and from observations made during the ABB-ES site inspections.

Many invertebrate species feed on flowers, fruits, and leaves of plants; conversely, invertebrates serve as prey items for a variety of predators, including predaceous insects, amphibians, reptiles, birds, and mammals. Invertebrates also serve as important detritivores, scavengers, and pollinators. Insects, as well as other invertebrates, are critical members of the various upland and wetland communities in the vicinity of BAAP. These invertebrate species form the faunal base of BAAP aquatic and terrestrial food chains, and are available for consumption by a range of higher predators.

The various small ponds and wetlands at BAAP are likely to support a typical southern Wisconsin warm water fishery. Aquatic species expected to occur in the Ballistics Pond include white bass (*Roccus chrysops*), yellow perch (*Perca flavescens*), bluegill sunfish (*Lepomis macrochirus*), and fathead minnow (*Pimephales promelas*). Results of the fish surveys conducted at BAAP are included in Table P-5, Appendix P.

A number of amphibian species probably occur in the vicinity of BAAP. True frog species, including the northern leopard frog (*Rana pipiens*), green frog (*R. clamitans*), and wood frog (*R. sylvatica*) might occur in the forested swamps and ponds in the vicinity of the site. Other known amphibians in the region include the northern spring peeper (*Hyla c. crucifer*), greater gray treefrog (*Hyla versicolor*), and American toad (*Bufo americanus*).

The most common upland reptiles in the vicinity of BAAP include the brown snake (*Storeria dekayi*), and eastern garter snake (*Thamnophis s. sirtalis*). Common snapping turtle (*Chelydra serpentina*), eastern painted turtle (*Chrysemys picta*), and northern water snake (*Nerodia sipedon*) all are probable residents of wetlands in the vicinity of BAAP.

BAAP is located in the "Mississippi Flyway" waterfowl migration route. Consequently, many bird species are expected to use portions of BAAP during migration as a feeding and resting area. BAAP may also function as an overwintering and breeding habitat for a number of avian species. Although disturbed, the terrestrial habitat atop the site's landfills may provide nesting habitat for several avian species, including the mourning dove (*Zenaida macroura*) and the killdeer (*Charadrius vociferus*). These species, and birds such as the American goldfinch (*Spinus tristus*), cow bird (*Molothrus ater*), meadowlarks (*Sturnella magna*), and song sparrow (*Melospioza melodia*) could forage in the open grassy pastureland at BAAP, and red-tailed hawks (*Buteo jamaicensis*) and other raptors may hunt over the site's extensive open fields. Culturally disturbed palustrine and emergent marsh habitats at BAAP likely provide habitat for a variety of avifauna, including herons, such as redwing blackbirds (*Agelaius phoeniceus*), marsh hawks (*Circus cyaneus*), great blue heron (*Ardea herodius*), waterfowl such as the mallard duck (*Anas platyrhinchos*), wood ducks (*Aix sponsa*), and black duck (*Anas rubripes*), and flycatchers (e.g., the eastern kingbird, *Tyrannus tyrannus*). Raptors such as the sharp-shinned hawk (*Accipiter striatus*) may hunt along forest edges at the site, and numerous passerine songbirds (i.e., the swamp sparrow [*Melospiza georgiana*] and the red-winged blackbird [*Agelaius phoeniceus*]) are likely to occur in the site's wetlands. Secondary growth woodlands include oak and hickory tree species that are expected to provide habitat for many species of birds at BAAP, including the dark-eyed junco (*Junco hyemalis*), cardinal (*Cardinalis cardinalis*), blue jays (*Cyanocitta cristata*) and bobwhite quail (*Colinus virginianus*). A list of avian species potentially occurring at BAAP is appended as Table P-4 in Appendix P.

The mammalian fauna of BAAP includes white-tailed deer (*Odocoileus virginianus*), as well as secondary consumers such as red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), opossum (*Didelphis marsupialis*), and raccoon (*Procyon lotor*). Small mammals likely to occur at the site include various Chiropterans (bats), meadow voles (*Microtus pennsylvanicus*), moles (*Scalopus aquaticus*), gray squirrels (*Sciurus carolinensis*), short-tailed shrew (*Blarina brevicauda*), house mouse (*Mus musculus*), deer mouse (*Peromyscus maniculatus*), and eastern cottontail rabbits (*Sylvilagus floridanus*). Muskrats (*Ondatra zibethicus*) may feed on cattails in marshy wetlands at the site, and Mustelid species such as the mink (*Mustela vison*) may occur in the forested wetlands in the vicinity of the site. BAAP supports a herd of 250 to 400 white-tailed deer (Wegner, 1985), which are prevented from migrating by a 6-foot cyclone fence around the plant, although some have been known to jump the fence (Herron, 1984). These deer rely heavily on corn and alfalfa for food. A list of mammalian species potentially occurring at BAAP is appended as Table P-3 in Appendix P.

5.2.4 Habitats of Special Concern and Endangered Species

The 8- to 10-mile radius surrounding BAAP contains a number of state and federal threatened and endangered plant and animal species. The occurrence of these taxa is largely a product of the geology of the area, which is unique to southern Wisconsin. The Baraboo Hills are composed of quartzite with intermittent sandstone beds. Gorges and cliffs are common topographic features. The variable topography and substrate types provide habitat for a diverse number of species. Habitats located in the vicinity of BAAP that are known to contain significant numbers of threatened and endangered species include Pine Glen, which borders the northern boundary of BAAP; Devil's Lake and Devil's Lake Oak Forest (located 4 miles north of BAAP); Otter Creek Bluff, located just to the southwest of BAAP; and Baxter's Hollow 2 miles to the northwest of BAAP. Figure P-1 (Appendix P) indicates the location of those nearby habitats known to contain threatened and endangered species. Pine Glen Natural Area, a 160-acre, state-significant, designated natural area is located outside and along the northwestern boundary of BAAP in the southern flank of the Baraboo Hills. This natural area contains several natural communities, including southern and northern dry-mesic forest, southern dry forest, and cedar glade. Pine Glen also includes unusual erosional features and is designated as a National Natural Landmark (WDNR, 1989). Otter Creek Bluffs Natural Area is a 1,300-acre, non-designated natural area with a southern dry-mesic forest community. Information regarding state and federal watch list, threatened, and endangered species was provided to ABB-ES by WBER and the Nature Conservancy. Specific locations (with respect to BAAP) of sightings and habitats of all threatened and endangered species in the area were identified and the potential for these species to occur at BAAP assessed (Appendix P, Table P-6). Based on proximity of these areas to the site and habitat requirements, the following species might be expected to occur at BAAP: Purple Milkweed, Slender Bush-Clover, Woolly Milkweed, Gattinger's Agalinis, Nuttall's Prairie Parsley, Peregrine Falcon, Cooper's Hawk, and three species of warblers. Appendix P contains a brief description of the geographic ranges and habitat requirements of these species. In addition, the bald eagle (*Haliaeetus leucocephalis*), a federal and Wisconsin state threatened species, is known to roost and feed just south of the dam on Lake Wisconsin. This species is a summer resident in Wisconsin and has been reported to nest at a site located approximately 10 miles south of BAAP (WDNR, 1992).

However, to date no federal- or state-designated endangered species have been documented within the boundaries of BAAP. In addition to species that may occur at BAAP itself, aquatic species that occur in the Wisconsin River, especially north of the power dam on Lake Wisconsin, may also be affected by site-related contamination due to potential discharge of contaminated groundwater. Fish and mussel species known to occur in the Wisconsin river include Paddle Fish, Blue Sucker, Lake Sturgeon, Goldeye, Higgins' Eye, Paper Pondshell, and Elktoe.

Additional information on specific locations of aquatic fauna in the Wisconsin River has been requested and an updated list of threatened and endangered terrestrial species occurring in the Baraboo Hills (which is pending publication of the results of a three-year ecological study of the Baraboo Hills) will be reviewed when it becomes available. Additionally, a flora and fauna survey of the BAAP site is schedule to be conducted in 1993. Should additional information become available from these sources, the conclusions of the ecological assessment may require reevaluation.

5.3 ECOLOGICAL EXPOSURE ASSESSMENT

The purpose of the ecological exposure assessment is to evaluate the potential for ecological receptor exposure to chemical constituents at BAAP. This evaluation involves the identification of actual or potential exposure routes to receptors and evaluation of the magnitude of exposure to identified ecological receptors. In this subsection, exposure concentrations are estimated for each class of ecological receptor and for all relevant exposure pathways. This exposure information is used with the toxicological information presented in Subsection 5.4 to evaluate ecological risk..

Exposure pathways describe the mechanism(s) by which ecological receptors are exposed to contaminated media, and consist of a: (1) contaminant source; (2) environmental transport medium; (3) point of receptor contact; and (4) the exposure route (e.g., ingestion of prey items that have bioaccumulated contaminants in their tissues, drinking of contaminated surface water, incidental soil ingestion, dermal absorption, and inhalation). A general overview of the exposure pathways and contaminated media considered in the BAAP ecological risk assessment is presented in Tables 5-1 and 5-2.

Exposure pathways and receptors evaluated in this ecological risk assessment were chosen based on the characteristics of ecological receptors and communities at the site; the physical and chemical properties of the COCs; and the affected environmental media at the site. Exposure to aquatic and semi-aquatic receptors (including plants) has been evaluated via a direct comparison between Wisconsin and federal standards, and exposure point concentrations; either 95th percentile or maximum concentrations of contaminants in BAAP surface water and sediments were evaluated. Exposure to terrestrial ecological receptors has been evaluated via computer food web modeling.

5.3.1 Aquatic Biota

Aquatic organisms (including plants, invertebrates, fish, and amphibians) could be exposed to contaminants through dermal contact with and ingestion of contaminated surface water and sediments (including contaminated sediment particles and interstitial water). Bioconcentration and bioaccumulation may provide significant exposure pathways for consumers of aquatic organisms. Bioconcentration is defined as "the process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill and epithelial tissue) and elimination," whereas bioaccumulation is "a process by which chemicals are taken up by aquatic organisms from water directly or through consumption of food containing the chemicals" (Rand and Petrocelli, 1985). Bioaccumulation and bioconcentration from contaminated media potentially result in aquatic food chain effects, and could result in exposure to herbivorous, omnivorous, and carnivorous aquatic ecological receptors. Inhalation of VOCs could also present an exposure route to some aquatic receptors. Wetland plants may be exposed to contamination via root uptake from sediments and water.

The relative lack of ingestion data for predatory fish and invertebrates precluded an evaluation of the effects of ingestion of contaminated biota by fish, amphibians, and invertebrates. Therefore, to evaluate ecological risks to aquatic receptors, the exposure concentrations used in this ecological risk assessment are either the 95th percentile or maximum concentration detected in surface water and sediment.

5.3.2 Terrestrial Biota

Terrestrial organisms (i.e., birds, mammals, amphibians, reptiles, and terrestrial invertebrates) at BAAP could be exposed to contamination via incidental ingestion of surface soils, ingestion of prey items that have bioaccumulated chemicals in their tissues, inhalation of volatile constituents and airborne particles, and dermal uptake. Exposures via dermal uptake have not been assessed because little dermal uptake data are available. Dermal exposure may be an ecologically significant exposure pathway for amphibians and for young, hairless mammals, that are in intimate contact with soil. However, it is expected that fur, feathers, and chitinous integument will minimize dermal absorption for most ecological receptors. Inhalation exposures by ecological receptors are usually insignificant, except in emergency situations (i.e., following a chemical spill), and were not evaluated in the ecological risk assessment. No exposure pathways exist for groundwater at the site because terrestrial organisms are not expected to come into contact with this medium. Subsurface soils (i.e., those soils located two feet or more below grade) were not evaluated in the ecological risk assessment, because (1) the majority of readily available prey items exist in surface media, and (2) it is unlikely that most ecological receptors would come in contact with subsurface soils.

5.3.2.1 Terrestrial Receptors. For those SWMUs where terrestrial receptors are likely to occur, a food web model was employed to estimate the potential dietary exposure levels of contaminants for several potential receptor species representing various trophic levels within the ecological community at BAAP. The selected species were chosen because: (1) they could be ecological receptors at BAAP; (2) their various feeding habits (e.g., omnivorous, carnivorous) are representative of a typical Wisconsin ecological community; and (3) several of these species have been recommended for evaluation of ecological risks by USEPA and the USF&WS. Each species evaluated is assumed to be representative of other species within a trophic level at BAAP.

Identical ecological receptors were modeled at each of the ecological risk assessment study areas evaluated quantitatively (see Table 5-1). The following indicator species were selected to represent exposure to terrestrial organisms via ingestion of food and soil:

- Short-tailed shrew (*Blarina brevicauda*). This carnivorous small mammal has a limited home range, a small body size, and a voracious appetite (Godin, 1977), factors that increase the likelihood these organisms could encounter significant contaminant concentrations. It frequents open grass-covered areas and is active both day and night.

- Eastern Meadowlark (*Sturnella magna*). This inland member of the blackbird and oriole family feeds on a variety of grassland invertebrates. Approximately 74 percent of its diet consists of animal matter (Terres, 1987). This species may occur in the open grasslands of BAAP and at other similar habitat in the state, often in the vicinity of farmland or airfields. The meadowlark has been used to represent the primary and secondary consumer small bird community in open grassland habitat at BAAP.

- Garter Snake (*Thamnophis sirtalis*). This common carnivorous snake feeds on small mammals, invertebrates, and other reptiles and amphibians, and has a home range of approximately 5 acres. Although garter snakes occur in a variety of habitats, including open grasslands, they are most common in the vicinity of wetlands.

- Red fox (*Vulpes vulpes*). This omnivorous mammal prefers open woodlands and grassy fields, and is most active at night and during twilight periods. It is an opportunistic predator, feeding on small mammals, birds, amphibians, reptiles, and invertebrates, as well as berries and other fruits (Burt and Grossenheider, 1976). The red fox has a home range of approximately 250 acres and was chosen to represent the secondary and tertiary consumer mammal community at BAAP.

- Red-tailed Hawk (*Buteo jamaicensis*). This bird of prey prefers foraging in open country, frequently on woodland edges. It feeds primarily on small mammals, and also includes reptiles, small birds, and occasional invertebrates in its diet. Red-tailed hawks are year-round/seasonal residents at BAAP and are frequently seen perched adjacent to open fields. The red-tailed hawk has been chosen to represent the secondary and tertiary consumer avian community at all six sites evaluated in the BAAP food web model.

These five species were selected from the species identified in Appendix P because they are representative of the range of mammals, birds, and reptiles that could occur at the site. Exposure parameters for the selected species, which were used to estimate dietary exposure levels, are presented in Table Q-2, in Appendix Q. Although large herbivorous mammals (such as cattle and deer) were not modeled specifically, it is expected that exposure by these receptors would be less than for those organisms with smaller foraging ranges or those that include animal prey in their diet (and hence are more likely to be exposed to bioaccumulated compounds). In addition, cattle are only allowed to graze in areas where soil contamination has not been noted; cattle grazing restricted to the Nitroglycerine Area (excluding the Nitroglycerine Pond, which is fenced off) and in the extreme northern portion of the Rocket Paste Area (personnel communication with Randy Sprecher, 1992). Although deer have fairly unrestricted access to most of BAAP, the wide-ranging habitats of these animals are anticipated to limit dietary exposures. Moreover, TNT (and associated metabolites) were not detected in deer muscle and liver samples collected at BAAP and Alabama Army Ammunition Plant, suggesting that this species is not being significantly exposed to this class of compounds (Shugart, 1991; Shugart and Griest, 1990).

The food-web model was used to estimate contaminant levels in various prey items consumed by each identified receptor species. Estimated contaminant tissue residues in prey items were calculated using specific bioaccumulation factors (BAFs) obtained directly or extrapolated from values in the scientific literature. Because BAFs for a number of BAAP contaminants were not available in the literature, BAFs for these compounds were derived using regression equations (Lyman et al., 1990). BAFs were also used to model the transfer of surface soil constituents between trophic levels to estimate tissue concentrations in secondary prey items such as small mammals and reptiles. BAFs are presented in Table Q-1, in Appendix Q.

The following equation was used to estimate contaminant tissue residues in prey items:

$$\textit{Prey Tissue Concentration } (mg/kg) = \textit{Soil Concentration } (mg/kg) \times \textit{Bioconcentration Factor } (BCF)$$

The Potential Dietary Exposure (PDE) level, for each modeled receptor species, was calculated by multiplying each predicted prey species tissue concentration by the proportion of that prey type in the diet, summing these values, adding soil exposure, and multiplying by the receptor species' Site Foraging Frequency (SFF). Incidental soil ingestion associated with foraging, preening, and cleaning activities was conservatively assumed to represent 5 percent of total dietary intake for all modeled ecological receptors. The PDE is represented by the following equation:

$$PDE = \sum_{1 \to n} [P_1 \times T_1 + P_2 \times T_2 + \ldots P_n \times T_n + \textit{soil exposure}] \times SFF$$

where:

PDE = Potential Dietary Exposure (mg/kg)
P_n = Percent of diet represented by prey item n ingestion
T_n = Tissue concentration in prey item n (mg/kg); calculated by multiplying the chemical concentration in soil by a bioaccumulation factor
Soil Exposure = (0.05) (Soil concentration in mg/kg)
SFF = Site Foraging Frequency; Area of Contaminated Soil (acres)/Home range (acres)

The SFF term for modeled receptor species was not used when acute exposure concentrations were estimated (i.e., those associated with a single feeding episode) at any of the evaluated BAAP study areas. This was done because the ecological risk concern for acute exposures is not the probability that an organism will feed at the particular site, but rather what the exposure would be if an organism were to feed in the contaminated area. However, SFF terms for individual prey items consumed by secondary consumers were used in estimating the individual prey tissue contaminant concentrations.

Finally, the PDE for each receptor species was multiplied by the receptor-specific ingestion rate and divided by the estimated body weight to calculate a total body dose (TBD):

where:

$$TBD = PDE \times IR \times \frac{1}{BW}$$

TBD = Total Body Dose (mg/kgBW-day)
PDE = Potential dietary exposure (mg/kg)
IR = Ingestion rate (kg/day)
BW = Body weight (kg)

These TBD estimates are directly comparable to the available toxicological test data (discussed in the following subsection) and were used in conjunction with toxicological data to evaluate ecological risks.

5.4 ECOTOXICITY ASSESSMENT

The purpose of the ecotoxicity assessment is to describe the environmental risks associated with the identified COCs in each medium of concern, and to evaluate the relationship between the concentration to which an organism is exposed and the potential for adverse effects due to acute and chronic exposures. The toxicological evaluation includes the process of characterizing the inherent toxicity of the COCs and establishing reference or threshold toxicity values for each identified contaminant in all media evaluated. Information contained in the ecotoxicity assessment, in conjunction with exposure information presented in the previous subsection, is used to evaluate ecological risks to aquatic, semiaquatic, and terrestrial organisms in the ecological risk characterization.

From the toxicological data set evaluated, the lowest acute and the lowest chronic values for each representative species or medium were selected as the Reference Toxicity Values (RTVs) for each COC. These RTVs, which represent a threshold concentration for effects to aquatic and semiterrestrial organisms, are expressed as $\mu g/\ell$ for surface water, $\mu g/\ell$ for sediment/surface soil, and as the constituent dosage per unit body weight for terrestrial organisms (mg/kg BW (body weight)/day).

5.4.1 Toxicity to Aquatic Receptors

Aquatic receptors are possibly exposed to chemicals in surface water and sediments at BAAP. Therefore, it is necessary to evaluate the toxicity of site contaminants in both media. Contaminant toxicity in these two media has been evaluated through comparison with state and federal ARARs, laboratory-derived toxicological information, and toxicity threshold values developed using extrapolation techniques. These sources were used to generate acute and chronic RTVs for the majority of BAAP constituents in sediments and surface water; surface water and sediment RTVs are presented in Tables 5-3 and 5-4, respectively.

ARARs represent federal and state requirements that may govern the cleanup of hazardous waste sites (USEPA, 1989a). "**Applicable Requirements**" are those federal and state promulgated requirements that are legally applicable to the response action, whereas "**Relevant and Appropriate Requirements**" are federal and state requirements that are not directly "applicable" to the site in question, but are designed for sufficiently similar situations to make their application appropriate. In the absence of federal and state regulatory ARARs, state and federal criteria, guidance, advisories, and recommendations have been employed in evaluating risk at BAAP.

5.4.1.1 Surface Water. Information to evaluate the toxicity of BAAP surface contaminants includes Wisconsin and federal water quality criteria, laboratory-derived toxicity data, and toxicity threshold values developed using toxicological extrapolation techniques.

AWQC have been developed and published by the USEPA for the protection of aquatic life and human health. The aquatic life AWQC are intended to be protective of all life stages of aquatic animals and plants. These criteria specify the contaminant concentration in ambient surface water that, if not exceeded, should protect most species of aquatic life and their uses. The chronic criterion represents the contaminant concentration that should not be exceeded by the four-day average chemical concentration more than once every three years (USEPA, 1986b). In developing a chronic AWQC, USEPA estimates protective contaminant levels based on chronic toxicological data for animals, plants, and on residue levels in aquatic organisms. The acute criterion represents the level that should not be exceeded by the one-hour average concentration more than once every three years. USEPA has not yet developed national AWQC for all contaminants detected at BAAP. When USEPA Water Quality documents did not contain sufficient information to derive a AWQC, the Lowest Observed Effects Level (LOEL) was identified from USEPA Water Quality Criteria documents and used as the BAAP RTV.

Ambient water quality criteria have also been developed and published by Wisconsin. WAC Chapter NR 105 provides criteria for a number of the surface water constituents detected in the Nitroglycerine Pond, the Ballistics Pond, and the Rocket Paste Area Pond, as well as providing a methodology for developing criteria to protect (among other uses) the "propagation of fish and aquatic life and wild and domestic animal life". Available state criteria are presented in Appendix Q, Table Q-3; the site-related constituents for which state criteria exist include: arsenic (AS), CR, CU, PB, NI, and ZN. The criteria presented in Table Q-3 were developed for the general state water body classification which meet the "All Other Fish and Aquatic Life Subcategories," as described in WAC Chapter NR 102.

In addition to criteria designed to be protective of the propagation of fish and aquatic life, Wisconsin has also developed a methodology for deriving criteria protective of drinking water and consumption of contaminated aquatic prey items by wild and domestic animals. Wildlife and Domestic Animal Values (WDAVs) were developed for each taxonomic grouping based on available toxicological data presented in Appendix Q, Table Q-3. The lowest taxon WDAV for each COC detected in surface water samples at BAAP was then chosen as the Wildlife and Domestic Animal Criterion (WDAC). These criteria are presented in Table Q-3. The surface water RTV was selected as the lowest of the three criteria values (i.e., USEPA chronic AWQC, Wisconsin chronic water quality criteria (WQC), and the WDAC). Surface water RTVs, which were used to evaluate potential exposures to all ecological receptors to surface water constituents in the Nitroglycerine Pond, the Ballistics Pond, and the Rocket Paste Area Pond, are presented in Table 5-3.

5.4.1.2 Sediments. Limited data are available to evaluate the potential for toxic effects of BAAP sediment contaminants on aquatic life. Available information includes state and federal sediment quality criteria and guidance, laboratory-derived toxicity data, and toxicity threshold values developed using toxicological extrapolation techniques.

Sediment Quality Criteria (SQC) for a number of hydrophobic organic compounds have been developed and published by the USEPA (1988c). No USEPA SQC are available to evaluate the effects of inorganic constituents on aquatic life. The USEPA SQC criteria are intended to protect benthic organisms that are primarily impacted by contaminants in the interstitial water between sediment particles. USEPA developed SQC using an equilibrium partitioning approach to identify sediment concentrations that could be associated with interstitial water concentrations equal to chronic AWQC.

Aquatic and benthic organisms are typically exposed to sediment contamination as a result of contact with contaminated interstitial water (USEPA, 1989b). For non-polar, hydrophobic organic compounds, such as PCBs, the degree to which compounds are released from sediment particles into the interstitial water is strongly influenced by their low solubility and strong binding affinity to TOC within the sediment particle. The higher the TOC content of the sediments, the lower the potential for contaminant release to the interstitial water. Conversely, those sediments with low TOC concentrations tend to have a higher potential for contaminant release into the interstitial water.

Therefore, the toxicity of sediments containing hydrophobic compounds (and subsequently the associated sediment toxicity criteria) varies on a site-specific basis in an inverse relationship with the fraction of sediment that is organic carbon. For this reason, sediment toxicity threshold criteria are often normalized to reflect TOC: carbon-normalized data are expressed as μg contaminant per gram of organic carbon (μg/gC) in sediment. A site-specific criterion can be calculated by multiplying the organic carbon-normalized criterion by the fraction of TOC present in typical sediment samples at BAAP. The USEPA freshwater SQC for phenanthrene (PHANTR) (1,390 μg/g, assuming 1 percent TOC) was used to evaluate potential aquatic exposures at the Ballistics Pond where this compound was detected.

Sediment quality standards and guidance values for a subset of the constituents detected in sediments at BAAP have been developed by the WDNR (Sullivan et al., 1985). State SQC are available for CR, PB, and HG; all three criteria were developed based on concentrations deemed representative of background conditions for Wisconsin. These criteria were used to evaluate the impacts to aquatic organisms associated with exposure to sediment at the Nitroglycerine Pond, the Oleum Plant Pond, and at the Ballistics Pond.

No state or federal SQC are available for other sediment constituents detected at BAAP. Other compilations of sediment threshold levels and guidelines were used to characterize the potential toxicity of ammonia (NH3) and NIT (documented in Appendix Q, Table Q-3); however, no toxicological data for AL or SO4 are available.

5.4.2 Toxicity to Terrestrial Receptors

The purpose of the ecotoxicity assessment is to describe the environmental risks associated with the identified COCs, and to evaluate the relationship between the concentration to which an organism is exposed and the potential for adverse effects from acute and chronic exposure.

The toxicological evaluation includes the process of characterizing the inherent toxicity of the COCs. Potential impacts to ecological receptors at estimated exposure concentrations were evaluated using published laboratory-derived toxicological data, as well as threshold toxicity values developed using extrapolation techniques. Both acute and chronic exposure concentration/response studies have been considered in the ecotoxicity assessment. From the toxicological data set evaluated, the lowest acute and the lowest chronic values for each representative species were selected as the RTVs for each COC. These RTVs, which represent a threshold dosage for effects to terrestrial organisms, are expressed in mg/kg BW (body weight)/day (Appendix Q, Table Q-4) and are summarized in Table 5-5.

In general, the Lowest Observed Adverse Effect Levels (LOAELs) were used as the chronic RTV. In cases where no chronic RTV data were available, two factors were applied to the acute LD_{50} (the single dose lethal to 50 percent of the test organisms). These factors are: (1) a factor of 0.2 for extrapolating from the oral LD_{50} to a value expected to protect 99.9 percent of the population from acute effects (USEPA, 1986c); and, (2) a factor of 0.1 for extrapolating from acute to chronic values (the acute-chronic ratio for many chemicals is approximately 10) (Newell et al., 1987).

A number of the concentration/response studies reviewed for the ecological risk assessment evaluate the toxic effects of contaminants on either laboratory rats or mice; however, many toxicological studies with minks, dogs, birds, and other receptor taxa were also reviewed. Whenever possible, RTVs were selected to represent the closest phylogenetically related ecological receptor species. For instance, RTVs for the small mammal ecological receptors typically have been based on laboratory rat studies, whereas, whenever possible, avian ecological receptor RTVs have been based on avian concentration/response studies. Likewise, if dog or mink concentration/response studies were available, RTVs for the red fox were based on these studies, rather than on avian or rat studies.

Ingestion toxicity data and terrestrial RTVs for BAAP are presented in Appendix Q, Table Q-4.

5.5 ECOLOGICAL RISK ASSESSMENT

This subsection characterizes the risk to aquatic, semiterrestrial, and terrestrial receptors potentially exposed to surface water and sediment contaminants at BAAP. The ecological risk is dependent on the magnitude, duration, and frequency of exposure to the site contaminants, and on the characteristics of the exposed populations. The BAAP exposure information (see Subsection 5.3), combined with the BAAP ecotoxicity information (see Subsection 5.4) provides the basis for the risk characterization.

5.5.1 Risks to Aquatic Receptors

In this subsection, the potential risk associated with exposure to surface water in BAAP wetlands and seeps, and sediment in BAAP wetlands are evaluated.

5.5.1.1 Risks Associated with Surface Water Exposure. Comparison of the contaminant concentrations detected in BAAP wetland surface water with RTVs for aquatic organisms provides a means to evaluate the potential for adverse effects on aquatic environmental receptors from exposure to surface water contaminants. For each study area, comparisons have been made between the surface water RTV (developed as discussed in Subsection 5.4.1.1) and the estimated exposure point concentrations of BAAP surface water COCs (Table 5-3). Site-specific risk evaluation results for surface water exposures are discussed in the site-specific Sections 6.0 through 11.0 of this report.

5.5.1.2 Risks Associated with Sediment Exposure. Comparison of the contaminant concentrations detected in BAAP sediments with RTVs for aquatic organisms provides a means to evaluate the potential for adverse effects on aquatic environmental receptors from exposure to sediment contaminants. To evaluate risk associated with exposure to contaminated sediment at BAAP, comparisons were made between the sediment RTVs and exposure point concentrations of BAAP sediment COCs (Table 5-4). Site-specific risk evaluation results for sediment exposures are discussed in the site-specific Sections 6.0 through 11.0 of this report.

5.5.2 Risks to Terrestrial Receptors

Risks to terrestrial receptors at BAAP were quantitatively evaluated using HQs, which were calculated for each COC by dividing the estimated exposure level, in terms of TBD, by the toxicological benchmark (the RTV). To calculate acute exposure HIs, the site-specific exposure point concentration of each COC was divided by the acute RTV; chronic exposure HIs were calculated by dividing the site-specific exposure point COC concentrations by the appropriate chronic RTV. This conservative approach provides a screening level evaluation of potential effects of individual COCs on terrestrial ecological receptors.

Cumulative HIs were determined by summing the HQs for each chemical. A hazard ranking scheme developed by USEPA (1989a) was used to characterize the potential risk associated with exposures to BAAP contaminants. Cumulative HI scores were classified using the following USEPA (1989a) ranking system:

HAZARD INDEX	EFFECTS EXPECTED
HI < 0.1	No Adverse Effects
0.1 < = HI < 10	Possible Adverse Effects
HI > = 10	Probable Adverse Effects

This ranking system considers potential ecological effects to individual organisms, and does not evaluate potential population-wide risks. Contaminants may cause population reductions by affecting birth and mortality rates, immigration, and emigration (USEPA, 1989a). In many circumstances, acute (or chronic) effects can occur to individual organisms with little potential population or community level effects; however, as the number of individual organisms experiencing toxic effects increases, the probability that population-level effects will occur also increases. The number of affected individuals in a population presumably increases with increasing HI values; therefore, the likelihood of population level effects occurring is generally expected to increase with higher HI values.

The TBD for each model terrestrial receptor species was calculated as described in Subsection 5.3. This TBD estimates the combined effects of exposure to contaminated BAAP surface soil. The TBD for each constituent was compared to the acute and chronic RTVs to develop acute and chronic HIs. Cumulative acute and chronic HIs were determined by summing the acute and chronic HQs for each contaminant; these results were evaluated using the hazard ranking scheme described above.

5.6 ECOLOGICAL RISK ASSESSMENT UNCERTAINTIES AND DATA GAPS

The prediction of ecological risks at BAAP involves several uncertainties and assumptions. Although many of the assumptions and uncertainties at BAAP are inherent in the ecological risk assessment process (i.e., pertaining to the development and formulation of the conceptual model), others are related to lack of data and information, and the inability to assess the impacts of natural environmental stochasticity (USEPA, 1992a). The uncertainty analysis identifies and, whenever possible, quantifies the uncertainty associated with all aspects of the ecological risk assessment, from selection of COCs to risk characterization. To the extent possible, the discussion of uncertainty analysis provides an evaluation of the effects of uncertainties on the risk assessment conclusions. This evaluation can: (1) provide insight regarding strengths and weaknesses of the ecological risk assessment; (2) contribute toward development of future actions and remedial alternatives; and, (3) provide a basis for obtaining additional information to reduce risk estimation uncertainty (USEPA, 1992a).

5.6.1 Uncertainties and Assumptions

Assumptions and uncertainties at BAAP include, but are not limited to the following:

1. The models used to estimate exposures involve numerous exposure parameters, some of which are values from the literature, and some of which are assumed or estimated. Efforts were made to select exposure parameters representative of a variety of species or feeding guilds, so that exposure estimates would be representative of more than a single species. However, numerous extrapolations relating measurement and assessment endpoints have been included in this ecological risk assessment. These include extrapolations between taxa, between toxicological endpoints, and from laboratory to field studies.

2. The exposure models assume that organisms will spend equal amounts of time in all habitats within their home ranges. In actuality, organisms will spend varying amounts of time in different habitats, which would affect their exposures. The limitation of this assumption is that exposures to the particular species modeled may be overestimated or underestimated in the model.

3. In selecting RTVs, the lowest toxicity value reported in available literature was selected. Therefore, the RTVs employed in this ecological risk assessment may conservatively overestimate ecological risk.

4. Information regarding the presence or absence of ecological receptors at the site was obtained from a review of literature, habitat characteristics, and contacts with natural resource agencies. Actual occurrence and/or utilization of the habitats associated with contaminated media by the majority of ecological receptors listed in Appendix P is uncertain, however.

5. Neither dermal contact nor inhalation were evaluated because of a lack of information concerning uptake rates for wildlife. Therefore, total ecological exposure could be greater than predicted based solely on modeled ingestion scenarios. However, the relative contribution of dermal contact to total ecological risk is expected to be much lower than that of food and soil ingestion, because of the protective fur, feathers, or hardened skin covering most species of semi-aquatic and terrestrial wildlife.

6. Chronic toxicity to small mammals, small birds, amphibians, and reptiles could result in reduced reproductive success, whereas acute toxicity may result in mortality in populations of these organisms. If populations of these smaller organisms are significantly reduced, because of either acute or chronic exposure, fewer prey items would be available for predatory birds and mammals. Although predatory birds and mammals might stop foraging in areas with reduced prey populations, these secondary consumers may not always be otherwise directly affected, unless their total forage base was significantly reduced.

7. The hazard ranking scheme evaluates potential ecological effects to individual organisms, and does not evaluate potential population-wide risks. In many circumstances, acute or chronic effects may occur to individual organisms with little potential population or community level effects; however, as the number of individual organisms experiencing toxic effects increases, the probability that population-level effects will occur also increases. As a result of this assumption, the calculated risk may overestimate the true community or population level effects. Due to uncertainties regarding potential exposures to species of special concern, the evaluation of effects on individual organisms, as was conducted in this evaluation, may be appropriate. However, the focus on this level of organization should be reevaluated following the scheduled survey of flora and fauna at BAAP.

8. The exposure modeling does not consider the possibility that many ecological receptors discriminate and avoid consuming contaminated prey items (especially those that are most contaminated and would pose the most significant toxicological impact). This simplification could result in overly conservative estimates of potential exposure. Conversely, contaminated prey items may be selectively consumed if physiological, morphological, or behavioral effects make them more apparent or vulnerable. If this is the case, the calculated risk could be underestimated in the model.

9. A number of conservative toxicological and ecological assumptions have been made in this ecological risk assessment. As a result of the cumulative impact of multiple conservative assumptions, risk to ecological receptors may occasionally be predicted at soil chemical concentrations within the range of naturally occurring background levels.

10. Necessary uptake information for various constituents were not available in the literature, and regression equations were employed to develop BAFs. The values derived from this method are not precise and because they determine directly the estimated dietary exposure concentrations, can introduce considerable uncertainty in the risk process. Field studies designed to assess the actual bioavailability of soil constituents would be useful to address this issue.

11. Comparisons of 95th percentile or maximum contaminant surface water concentrations to chronic AWQC results in a "worst case" analysis. This approach likely results in an overly conservative risk evaluation of typical exposure conditions in aquatic media at BAAP.

6.0 PROPELLANT BURNING GROUND, LANDFILL NO. 1, SETTLING PONDS AND SPOILS DISPOSAL AREA

The Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area are disposal facilities located near one another in the south portion of BAAP. Since they share similar geologic, hydrogeologic, and environmental settings, these sites are discussed together in this section.

6.1 CURRENT AND PAST DISPOSAL PRACTICES

6.1.1 Propellant Burning Ground

The Propellant Burning Ground is located in the southwestern portion of BAAP and is made up of several distinct areas (Figure 6-1) including the Contaminated Waste Area and 1949 Pit Area, which are no longer active, but have been in existence and used since sometime after 1942. The Contaminated Waste Area and 1949 Pit Area combined are approximately 6 acres in size and currently contain three former waste disposal pits (designated WP-1, WP-2, and WP-3), a large open area used for burning propellant-contaminated materials (i.e., the Old Burn Area), and an area adjacent and west of the Contaminated Waste Area designated as the 1949 Pit. WP-1 has been backfilled with soil. WP-2 and WP-3 currently exist as open depressions each approximately 40 feet in diameter by 12 feet deep. The 1949 Pit has been backfilled with soil.

The Racetrack/Burning Ground, located south of the Contaminated Waste Area, is an oval gravel road. Currently, two concrete Burning Pads (designated BP-1 and BP-2) are located on the western side of the racetrack. BP-1 is currently active and contains a metal burning dish used to burn small amounts of waste propellant. BP-2 is currently inactive. Former facilities located at the Racetrack/Burning Ground include the Burning Plates located on the eastern side of the racetrack, and three inactive refuse burning pits (designated RP-1, RP-2, and RP-3) southeast of the racetrack. A review of aerial photographs indicates this area was constructed sometime between 1949 and 1955. In 1949 aerial photographs, this southern area is undeveloped and appears as cropland. The 1955 aerial photographs show the constructed racetrack, Burning Pads, and Burning Plate areas.

The Burning Ground/Racetrack Area also contains an active decontamination oven used to remove remnants of propellant from metal objects scheduled for maintenance, salvage, or scrap (Warzyn, 1982b). The decontamination oven is located approximately midway between the northern and southern areas of the Propellant Burning Ground.

The entire Propellant Burning Ground encompasses approximately 80 acres area (Sarko, 1981). The surface area of the existing pits, pads, and the open-burning area in the Propellant Burning Ground is approximately 35,900 square feet, or 0.82 acre.

The Propellant Burning Ground is operated by the BAAP maintenance department. This area originally was regulated under WAC, Chapter NR 181. In 1978, License No. 2814 was issued by the state for thermal treatment of wastes in this unit. In accordance with WAC, Chapter NR 181, WDNR issued an RCRA interim status license on April 2, 1986, which remains in effect at this time (Didier, 1987). WAC Chapter NR181 has since been replaced by the WACNR 600 series.

According to the MEP, open burning on bare ground was carried out to dispose of waste explosives and propellants and explosive-contaminated wastes from plant start-up until January 1983 (Tsai et al., 1988). In 1983, procedures for open burning of propellants and explosives were modified to meet the January 25, 1983, requirement prohibiting open burning on bare ground. Modifications included construction of a steel burning dish and decontamination oven.

Landfill 1 is included in this subsection because of its proximity to the Propellant Burning Ground. The history of activity at Landfill 1, however, may not be directly related to historical activities at the Propellant Burning Ground.

To assist in the assessment of historical activities at the Propellant Burning Ground, ABB-ES reviewed aerial photographs of the area. Photographs from 1940, 1944, 1949, 1955, 1962, 1968, 1974, 1978, 1980, and 1986 were obtained from BAAP, USEPA, and the National Archives in Washington, D.C.

The aerial photographs provide a partial historical record of activity and site disturbance at various areas of the Propellant Burning Ground. However, most aerial photographs do not reveal the details of the specific activities occurring in each area. In addition, the procedures and methods as well as the types of materials burned or disposed of at the Propellant Burning Ground cannot be clearly discerned by a review of aerial photographs. A composite, schematic chronology of active areas as seen in the aerial photographs is presented in Figure 6-2. Review of the photographs in chronological sequence indicates that Propellant Burning Ground features and type and location of disposal activity appear to change significantly during the periods of operation from 1944 through 1978.

Contaminated Waste Area. The Contaminated Waste Area is located approximately 500 feet north and slightly east of the Racetrack Area (see Figure 6-1). It consists of three large open pits (each approximately 40 feet in diameter and 12 to 15 feet deep) and the Old Burn Area. This area became active some time between 1942 and 1949, but is now inactive. The pits were last used in January 1983; it is not known when the Old Burn Area was last used. Organic solvents, propellant-contaminated wastes, and lumber were formerly burned in open pits. Reportedly, these Waste Pits were also used for the dumping/burning of process chemicals (Kearny, 1987). The Installation Assessment Report stated that as much as 500 gallons per week of a mixture of 24DNT, 26DNT, DNBP, DPA, C6H6, and other chemicals may have been dumped and/or burned in these pits from 1966 to 1977 (USATHAMA, 1977). One pit, WP-1, has since been filled with a silty clay soil and graded to conform with existing area topography. Boring data indicate that about 8 to 10 feet of soil fill exists in WP-1.

According to the MEP, solvent and solvent-containing solid wastes were burned at the Propellant Burning Ground along with propellants and propellant contaminated wastes (Tsai et al., 1988). The most likely locations of solvent disposal and burning are the three Waste Pits and three Refuse Pits in the Contaminated Waste Area and Racetrack Area, respectively. It is also likely that solvents were burned or disposed of in the Old Burn Area in the Contaminated Waste Area, and possibly in the Burning Pads and Burning Plate areas (especially before installation of the current concrete and steel burning apparatus). TRCLE was used from 1966 to 1974 and was burned with lumber in the area of the three Waste Pits (USAEHA, 1985). Tsai et al., also report that explosive and explosive-contaminated wastes were burned at the Propellant Burning Ground. According to BAAP operating history (Tsai, et al., 1988), military explosives such as 2,4,6-trinitrotoluene (246TNT), RDX, HMX, and tetryl and explosive ordnance were not manufactured, used, stored, or disposed of at BAAP (USATHAMA, 1977). However, the propellant additives 24DNT and 26DNT as well as NG, a component of various propellant formulations, are technically explosives. The MEP data summaries of previous analyses for 246TNT, RDX, HMX and tetryl explosive compounds did not indicate the presence of these types of explosive-type compounds. Because of the previous site data and operating history (Tsai, et al. 1988), the explosives 246TNT, RDX, HMX, and tetryl were not identified as contaminants of concern for BAAP; therefore, analyses conducted on environmental samples collected by ABB-ES as part of the RI did not include analysis for these explosive compounds.

As described, there is no evidence of activity in the southern portion (current Racetrack Area) of the Propellant Burning Ground in 1949. A pit (designated as the 1949 Pit), is shown extending southward in the western portion of the Contaminated Waste Area (see Figure 6-2). This pit, not identified in previous investigations, shows evidence of activity as well as the presence of many unidentified objects. Activity is not evident in the eastern portion of the Contaminated Waste Area and other pits are not visible. The 1949 Pit appears in the 1955 photographs as a partially filled depression. Barren soil and possible burning activity is apparent in the 1955 aerial photograph of the Contaminated Waste Area.

The 1962 and 1968 aerial photographs show the 1949 Pit covered and revegetated. The 1962 aerial photographs also show unidentified material piled inside the road that encompasses the Contaminated Waste Area. Waste Pits WP-1, WP-2, and WP-3 are not evident in the 1962 photographs. Burning activity is apparent in the eastern portion of the Contaminated Waste Area near the center of the perimeter road. WP-1, WP-2, and WP-3 are clearly seen in the 1974 aerial photographs. In addition, 1974 photographs show a large stockpile of what appear to be containers, west of the Contaminated Waste Area. Large tank-like objects are also visible north-northwest of the Contaminated Waste Area. The tanks in the photographs were reportedly being flame-decontaminated (to remove explosive or propellant material) at that time (Olin, 1990a). Only the 1974 aerial photographs show possible evidence of the three Refuse Pits at the southern end of the racetrack, which were described in the MEP as being used from plant start-up to 1983. No evidence of activity inside the racetrack road can be seen in aerial photographs taken from 1949 through 1986. Aerial photographs from 1978 show a barren area at the location of the covered pit, WP-1, which is located in the northwestern portion of the Contaminated Waste Area. Two of the three Waste Pits are plainly visible in the 1978 aerial photographs.

Racetrack/Burning Ground Area. Historical aerial photographs indicate that the Racetrack Area and associated Burning Pads and plates and Refuse Pits were not constructed or active until after November 1949. The two concrete Burning Pads in the Racetrack Area measure approximately 24 by 30 feet and were constructed after June 1978 and before 1986. Burning Pad 1 contains a steel burning dish, 42 inches in diameter. Installed in 1983, it is currently used to burn waste propellants. Burning Pad 2 is not currently in use and does not have a burning dish. Existing literature indicates that up to 100 pounds of nonspecification propellant is burned at a time in the burning dish at Burning Pad 1. Some propellants, particularly those of rocket paste formulations, contain PB compounds. Currently, ash and residuals generated in the Burning Pad area are placed in drums and stored in the on-site permitted hazardous waste storage area while awaiting characterization for disposal.

Before the concrete Burning Pads were constructed and the burning dish installed (before 1983) in this area, powder and waste material were burned directly on the ground. Materials burned on the ground in this area included NC, ball propellant, NG-containing compounds, and waste propellant paste. In addition, CCL4 might have been burned with propellants from 1942-45, 1951-56, and 1966-71 (USAEHA, 1985). A maximum of 100 pounds of propellant-containing wastes, at a 3-inch maximum depth, is burned at one time (Kearny, 1987). As a result, PB and propellant residues have been detected in soil samples collected from this area during previous investigations.

The eastern edge of the oval Racetrack Area, referred to as the Burning Plates area, was used to dry and burn wet NC on open steel, gas-fired grills.

Each of the three shallow Refuse Pits on the southern edge of the burning ground is reported to have been 15 to 30 feet in diameter. The pits were used for open burning of empty containers in which propellant materials were delivered and stored (Kearny, 1987). Organic solvents reportedly were burned in these Refuse Pits in conjunction with contaminated refuse. These Refuse Pits are not visible in the 1944, 1949, 1955, 1962, and 1968 aerial photographs. A 1978 aerial photograph indicates some evidence of activity, possibly associated with the Refuse Pits. It has been reported that as part of the interim waste measure to clean out the Rocket Paste Area outfall ditch, each Refuse Pit was filled with propellant-contaminated soils collected from the Rocket Paste Area outfall ditch and covered with a polyethylene cap (Tsai et al., 198 In September 1985, visibly contaminated soil in these pits was removed, including the soils 3 feet below the visible contamination. Two-hundred-twenty-two 55-gallon drums of soil (approximately 279,000 pounds) were excavated from these pits. This soil is currently held in a magazine building. The Refuse Pits were refilled with clean soil and reseeded as an interim remedial action (Fordham, 1987a). The 1986 aerial photographs do not indicate the presence of the Refuse Pits. Because the Refuse Pits are not visible in aerial photographs taken before 1978, it is likely that the use of Refuse Pits for burning and disposal of solvent-contaminated waste and propellants was of limited duration.

The decontamination oven is located approximately halfway between the southern racetrack and the northern Contaminated Waste Area. The oven is approximately 20 by 60 feet in size, and is used to decontaminate drums, containers, and/or equipment that could contain explosive or propellant materials. These materials are decontaminated in the oven by flashing under controlled temperatures (up to 700 degrees Fahrenheit) before being taken to the shop for maintenance or to the scrap yard for salvage or sale.

6.1.2 Landfill 1

Landfill 1, located approximately 400 feet east of the Contaminated Waste Area, is a waste disposal area reported to be approximately 300 by 200 feet (see Figure 6-1) (Kearny, 1987). The facility was reportedly used between 1942 and 1959 (Tsai et al., 1988). Based on aerial photographs, this area was originally excavated between 1944 and November 1949. Approximately 600,000 cubic feet of solid waste was reportedly disposed of in the landfill. The types of waste included structural timbers, asphalt shingles, cardboard, office refuse, and other unknown wastes generated from various BAAP unit operations. During ABB-ES' site reconnaissance in August 1988, pipe insulation material was observed in rubble on the ground surface at the site. This material, tested by Olin in January 1990, was found to be asbestos (Olin, 1990a). All exposed asbestos was removed shortly thereafter. The MEP reported that in addition to receiving wastes for disposal, open burning of propellants, extraction wastes (e.g., DNTs, DNBP, and DPA), C6H6, and black powder was conducted at the landfill. Both hazardous and nonhazardous wastes are believed to be buried in Landfill 1 (Tsai et al., 1988).

Aerial photographs of Landfill 1 from 1944, 1949, 1955, 1962, 1968, 1974, 1978, and 1986 were reviewed. The 1949 photographs indicate that Landfill 1 was apparently an open, bulldozer-excavated pit, located east of the Propellant Burning Ground. In a 1955 photograph, an open pit is visible at this location; however, the sides and slopes are eroded and there is no evidence of landfilling activity. The 1968 aerial photographs show active landfilling at Landfill 1. Landfill 1 is completely filled and revegetated in the 1974 photographs.

Aerial photographs show Landfill 1 in sufficient detail to estimate the size and depth of the excavation. The pit in the 1949 aerial photograph was approximately 300 to 350 feet long by 100 feet wide. In 1949, the maximum depth was estimated to be 12 to 15 feet. Maximum depths in 1962 and 1968 were estimated to be 10 to 12 and 8 to 10 feet, respectively. Filling before 1968 could represent natural slumping of the side slopes. In 1968, active filling from the northern side is apparent. Aerial photographs indicate the landfill was probably about half the width reported by Kearny, and that maximum capacity based on aerial photograph interpretation was 400,000 to 500,000 cubic feet (Kearny, 1987). It is likely that fill volume was substantially smaller than the 600,000 cubic feet reported in the MEP. The 1974 aerial photographs show Landfill 1 filled and covered. In addition, these photographs show some mounds of material apparently end-dumped in rows along the northern side of the pit area. This material appears to correspond to the demolition debris observed during the ABB-ES site reconnaissance of August 1988.

6.1.3 Settling Ponds and Spoils Disposal Area

The Settling Ponds and Spoils Disposal Area is located in the south-central portion of BAAP (Figure 6-3). It consists of Final Creek, the Settling Ponds, and the Spoils Disposal sites.

During the first 30 years or more of intermittent operations, Final Creek and the four Settling Ponds, along the southern boundary of BAAP, received sewage (which had undergone primary treatment) and neutralized industrial wastewater from most areas of the facility, and surface runoff from the Nitroglycerine, Rocket Paste, and Magazine areas. The wastewater treatment plant (WWTP) was constructed in the mid-1970s. Domestic sewage and liquid laundry waste from BAAP, with the exception of that from the Oleum Plant and Rocket Paste areas, currently flow to the WWTP. The WWTP facility provides primary and secondary treatment of collected sanitary wastewater with a capacity of 0.5-million gallons per day (mgd). The system, capable of treating an equivalent residential population of 10,000 to 12,000 people, consists of an Imhoff tank, lift pumps, a high-rate trickling filter, a clarifier, and chlorinator. The trickling filter was added to further reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Effluent from the WWTP flows to the unlined outfall ditch (i.e., Final Creek), where it combines with the general purpose sewer effluent from the drainage ditch. The Settling Ponds, with a total area of 40 acres, served as aeration and settling basins for the treated effluent. Clarified wastewater exits the facility into Gruber's Grove Bay. The creek and the ponds are unlined, allowing wastewater to seep into the ground.

The Settling Ponds were first used in 1941, according to the MEP. Settling Pond 1 was dredged and enlarged in 1970. During standby periods, Settling Pond 1 typically receives flow that fills Settling Pond 1 to a surface area of approximately 0.1 acre (Fordham, 1987a). Most often flow either evaporates or infiltrates in Settling

Pond 1. Settling Ponds 2 through 4 received flow only during plant mobilization (Tsai et al., 1988). The characteristics of Final Creek and the Settling Ponds are as follows (Kearny, 1987; and Ayres, 1984):

- Final Creek, which is about 2,000 feet long, receives effluent from the WWTP that flows into Settling Pond 1; before the mid-1970s, neutralized wastewater was discharged into Settling Pond 1.
- Settling Pond 1 has an effective surface area of 24 acres; its potential volume is about 31 million gallons, based on an average depth of 4 feet.
- Settling Pond 2 receives wastewater from Settling Pond 1 as sheet flow over a dam. It is a small pond, with a potential volume of about 1 million gallons.
- Settling Pond 3 is about 2,700 feet long, and has an area of about 8 acres and a potential volume of 6.5-million gallons. The pond receives wastewater from Settling Pond 2 and runoff via the drainage ditch from the central area of BAAP, including the Nitroglycerine, Rocket Paste, and Magazine areas.
- Settling Pond 4 has a surface area of 6 acres, and a potential volume of about 5.4-million gallons based on an average depth of 3 feet. This pond has a 20-foot semicircular weir structure controlling outflow with a remote monitoring station for pH and water level measurements.

The Spoils Disposal Area, containing five unlined spoil sites, is next to Settling Ponds 3 and 4 (see Figure 6-3). Spoils Sites 1 through 4 have been used for disposal of dewatering sludge and dredge spoil removed from the Settling Ponds. Spoils Sites 1 and 2, located north and adjacent to Settling Pond 3, contain dredge spoils hydraulically removed from the Settling Ponds. Spoils Sites 3 and 4, located south and adjacent to Settling Pond 3, contain hydraulically removed dredge spoils covered with sludge mechanically dredged from the Settling Ponds. Dredging activities began in late 1971 and ended in early 1973.

Spoils Site 5 is a 5-acre unit initially developed in the early 1970s to receive dredged spoils and water from cleanup operations of Gruber's Grove Bay, where effluent from the Settling Ponds enters the Wisconsin River. The dredging of Gruber's Grove

Bay, however, was not initiated. Because Gruber's Grove Bay was not dredged, Spoils Site 5 was not used for its intended purpose. It is currently lined with silty soil material about 1 foot deep, which reportedly was dredged from the Settling Ponds (Kearny, 1987; Ayres, 1984).

6.1.4 Interim Remedial Measure Facility History

The Interim Remedial Measure (IRM) is an interim facility designed to extract and treat contaminated ground water from beneath the Propellant Burning Ground. This system was installed at the request of the WDNR, and became operational in May, 1990. The system is composed of four extraction wells (Source Control Well (SCW)-1, located between the Contaminated Waste Area and the Racetrack, and Boundary Control Well (BCW)-1, -2, and -3, located approximately 3,000 feet south of the Racetrack), and a treatment system consisting of two carbon adsorption units and an air stripping unit. Locations for the extraction wells were based on results of the MEP, which relied on data collected prior to 1986. The four extraction wells are each currently pumped at a rate of 50 to 100 gallons per minute. Treated groundwater is discharged via a buried force main to the Wisconsin River approximately 2.5 miles upstream of the WP&L dam. Evaluation of the capture zones of BCW-1, -2, and -3 is discussed in Subsection 6.3.5.6.

6.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

The following subsections describe the field program activities and rationale. Table 6-1 summarizes the program elements. Conduct of the field program was specified in the following documents: (1) Sampling Design Plan (Data Item A004), (2) QC Plan (Data Item A006), and (3) HASP (Data Item A009).

6.2.1 Soil Vapor Survey

In October through November of 1988, Northeast Research Institute, Inc. (NERI), as a subcontractor to ABB-ES, conducted a Petrex Soil Gas Survey at the Propellant Burning Ground at BAAP. NERI's standard operating procedures for applying the Petrex technique to environmental soil gas surveys are described in Appendix B, which contains information on laboratory collector preparation, field operations, collector analysis, mass spectrometer analysis and QC measures, data interpretation and presentation, and interpretation of Petrex maps.

NERI used a passive soil gas sample collection system wherein the sample collectors were installed 1 to 3 feet below ground surface at the sample location and were retrieved at a later date for analysis.

A total of 135 Petrex soil gas collectors were used to screen samples at the Propellant Burning Ground (Figure 6-4). Historical data and/or the ongoing groundwater monitoring program conducted by Olin indicate contamination of soils and groundwater with VOCs and SVOCs. In some site areas, these historical and recently collected data were inadequate to locate and define existing contaminant sources. The objectives of the soil vapor survey were to collect and analyze VOCs and SVOCs from the soil gas, and map the distribution of detected components to determine whether significant hot spots existed. Soil vapor surveys were completed before initiation of surface soil sampling and monitoring well installations.

The collectors were installed by NERI personnel from October 19 through 21, 1988, and retrieved by NERI personnel from November 14 through 16, 1988 (see Appendix B for specific installation procedures). The collectors were located in the field by use of a hand compass and a tape. Each area's grid was referenced to the location of existing monitoring wells or cultural features (e.g., a road or fence).

6.2.2 Surface Soil Sampling

Surface soil samples were collected for laboratory analysis from 118 locations within three separate areas at the Propellant Burning Ground (Figures 6-5 and 6-6). The samples were collected to characterize the distribution of surface soil contamination in and around the former burning areas. Forty-one samples (i.e., PBS-91-01 through PBS-91-40 and PBS-91-49) were collected from the Burning Pads area. Sixty-nine samples (i.e., PBS-91-50 through PBS-91-118) were collected from a larger grid that includes the Racetrack and Burning Plates area. PBS-91-109 through PBS-91-118 were collected with hand augers at depths approximately 3 feet below ground surface to characterize the vertical extent of contamination in the Racetrack and former Burning Plates area. Finally, eight samples (i.e., PBS-91-41 through PBS-91-48) were collected from the Contaminated Waste Area (see Figure 6-6). Samples from the Burning Pads and Burning Plates area were spaced horizontally at 25 to 100 feet. Closely spaced samples (i.e., 25-foot spacing) were located near the Burning Pads and Plates while samples with larger spacing (i.e., 100- to 200-foot spacing) were located along the periphery of the Racetrack. The sample distribution was agreed upon following several discussions with WDNR and USEPA Region V.

6.2.3 Remote Sensing Geophysics

Geophysical surveys were conducted by ABB-ES at the 1949 Pit (August 1990) in the Propellant Burning Ground and at Landfill 1 (December 1988). The purpose of the surveys was to locate metallic objects in the 1949 Pit and to define the 1949 Pit and Landfill 1 boundaries. Information derived from these field activities was used for planning the locations for future explorations, including test pits, monitoring wells, and soil borings. The principles and applications of these geophysical techniques are described in Appendix C.

The geophysical techniques applied at the 1949 Pit included magnetometer and GPR surveys. Before geophysical surveying, a 260-by-600 foot survey area with a 20-foot grid spacing was established to serve as lateral control for measurements to follow. The survey coverage for the 1949 Pit is indicated in Figure 6-7.

The geophysical techniques applied at Landfill 1 included GPR and TC. Prior to profiling, a 100-by-100 foot survey grid was established at Landfill 1 to serve as lateral control for the final 300-by-500 foot grid. The survey coverage for Landfill 1 is indicated in Figure 6-8.

6.2.4 Test Pits and Soil Sampling

Eight test pits were excavated within the area of the 1949 Pit at the Propellant Burning Ground as part of the RI (Figure 6-7 and 6-9). The test pits (i.e., PBT-90-01 through PBT-90-08) were excavated to characterize the fill soils and to collect soil samples at depths ranging from 1 to 9 feet bgs for analysis.

The test pits were excavated with a Case Model 1088 track-mounted backhoe to a maximum depth of 16 feet bgs. Exploration logs for the test pits are presented in Appendix D. Laboratory analyses performed on the test pit soil samples are summarized in Subsection 6.2.11. Results of these analyses are discussed in detail in Subsection 6.4.3.4.

6.2.5 Soil Borings and Subsurface Soil Sampling

Thirteen soil borings were drilled at the Propellant Burning Ground, Settling Ponds and Spoils Disposal Area, and Landfill 1 as part of the RI to further characterize the subsurface geologic environment and assess the nature and vertical distribution of chemicals at these sites. The borings were drilled by John Mathes and Associates of St. Louis, Missouri, and Layne Northwest of Milwaukee, Wisconsin, as subcontractors to ABB-ES. Actual drilled footages, numbers of samples collected, and the purpose of the soil borings at the Propellant Burning Ground, Settling Ponds and Spoils Disposal Area, and Landfill 1 are listed in Table 6-2. The soil boring logs are shown in Appendix D. Laboratory analyses are summarized in Subsection 6.2.11. Results of subsurface soil sample analysis are discussed in detail in Subsection 6.4.3.4.

Eight 1991 soil borings in the Propellant Burning Ground and Settling Ponds and Spoils Disposal Area were advanced with 6.25-inch ID hollow-stem augers (HSAs). Three-inch ID split-spoon samples were collected continuously from each soil boring from the ground surface to approximately 22 feet bgs; at 5-foot intervals to a depth of 30 feet bgs; and at 10-foot intervals from 30 feet bgs to the groundwater table.

In 1990, four soil borings in the Propellant Burning Ground and Old Landfill were advanced with a dual-wall reverse air circulation, casing hammer technique. Soil samples were collected with 2-foot long, 3-inch ID split-spoon samplers. Soil samples were generally collected at 5-foot intervals from the ground surface to 25 feet; and at 20-foot intervals from 25 to 85 feet. The last sample from each boring was collected at the water table. Generally, subsurface soil samples from the Propellant Burning Ground, Settling Ponds and Spoils Disposal Area, and Landfill 1 were selected for laboratory chemical analysis from split-spoons collected in and just below the observed contaminated zones, as well as from each split-spoon collected at 5- and 10-foot intervals. The number of selected subsurface soil samples analyzed for the chemical parameters is indicated in Table 6-2. Drilling and sampling equipment was decontaminated between samples and borings by steam-cleaning with water from Production Well No. 2.

Ten soil borings were made at the Propellant Burning Ground (see Figure 6-9). The rationale for locating the borings and subsurface soil sampling requirements is summarized in Table 6-2. Specifically, two soil borings (i.e., PBB-90-01 and PBB-90-02) were drilled in the vicinity of the 1949 Pit. Three soil borings (i.e., PBB-91-01, PBB-91-02, and PBB-91-03) were drilled in Refuse Pits 1, 2, and 3, located south and east of the Racetrack. Three other soil borings (i.e., PBB-91-04, PBB-91-05, and PBB-91-06) were drilled in or immediately next to Waste Pits 1, 2, and 3, located in the northern and southern portions of the Contaminated Waste Area. PBB-91-07 was advanced through the Old Burn Area located in the central portion of the Contaminated Waste Area. Each boring (except PBB-91-07) extends down to the water table, approximately 100 feet bgs. PBB-91-07 was terminated at a depth of 76 feet because of a cobble zone that could not be penetrated by the HSAs.

The tenth soil boring at the Propellant Burning Ground utilized mud rotary drilling techniques to advance the boring (see Figure 6-9 and Table 6-2). This boring, designated PBB-89-10, was drilled south of the decontamination oven. PBB-89-10 extends from the ground surface to the sandstone bedrock (located approximately 260 feet bgs), and was used to characterize and correlate the stratigraphy of unconsolidated glacial deposits with the downhole/monitoring well geophysical survey data. Split-spoon samples were collected at 10-foot intervals throughout the entire borehole, and reference samples were taken from each split spoon; analytical samples of subsurface soils were not collected from PBB-89-10.

Two soil borings were drilled at Landfill 1 to determine the nature and depth of waste materials and to characterize the vertical distribution of any contaminants leached from this site. LOB-90-01, located near the center of Landfill 1, encountered 15 feet of waste material, including vitreous slag, ash, asphalt, and wood. This boring was advanced 141.5 feet bgs to the water table. LOB-90-02, located at the periphery of Landfill 1, encountered only 1 foot of waste over native soil. This boring was terminated at 20 feet because of a lack of visible contamination.

One soil boring, SPB-91-01, was drilled in the Settling Ponds and Spoils Disposal Area at Final Creek south of the wastewater treatment facility (Figure 6-10). SPB-91-01 extends from ground surface to the top of the water table.

6.2.6 Monitoring Well Installations

A total of 45 monitoring wells were installed by ABB-ES at the Propellant Burning Ground, Settling Ponds area, and Landfill 1. ABB-ES subcontracted and monitored the installation of 25 monitoring wells at 13 locations in the Propellant Burning Ground area, 13 monitoring wells at five locations in the Settling Ponds area, and seven monitoring wells at five locations in the Landfill 1 area. In addition, six 1-inch ID piezometers in two clusters were installed in the southern Propellant Burning Ground (see Subsection 6.2.9). Wells were installed by Layne Northwest of Milwaukee, Wisconsin, and Layne Environmental of Tempe, Arizona.

During the course of the RI field program several changes (as presented to WDNR and the USEPA) were made to the recommended location and depth of three of the wells at these sites (PBM-89-09, LON-89-02, and LON-89-03). PBM-89-09 was installed north of the Contaminated Waste Area because of the unknown and unidentified activities visible in 1944 and 1949 aerial photographs of the area. Wells LON-89-02B and LON-89-03B were added to the field program to characterize conditions downgradient from Landfill 1. Table 6-3 summarizes siting rationale and Figure 6-11 presents the locations of all new (1989 and 1991) and existing monitoring wells. These monitoring wells, in conjunction with existing wells installed during previous investigations, were sampled and tested to estimate hydraulic properties of the aquifer, rate and direction of groundwater flow, contour of the aquifer surface, and to monitor the presence of chemicals in groundwater by sampling and analysis.

1989 and 1991-series monitoring wells were installed within the study areas using either 6.25-inch ID HSAs or 6-inch ID and 10-inch OD dual-wall driven casing. Seven borings were advanced with HSAs to install shallow or intermediate depth wells. The remaining 45 borings were advanced using 10-inch OD dual-wall driven casing to install shallow, intermediate, and deep wells. The borings and subsequent well installations were completed at the three sites to (1) identify shallow and deep geologic conditions at each site, (2) obtain reference and geologic soil samples, (3) observe groundwater levels, (4) conduct in situ permeability tests, and (5) obtain water samples for laboratory chemical analysis. The location and rationale for each boring and monitoring well are discussed in the following subsections.

Split-spoon samples were generally collected at 10-foot intervals from selected monitoring well borings advanced with HSAs. Samples of soil recirculated to the surface through the center of the 6- and 9-inch dual-wall casing were collected and visually logged from individual monitoring well borings and the deepest boring in each well nest. The monitoring wells, consisting of flush-threaded, 4-inch Schedule 80 PVC, were installed in each borehole at the completion of each boring. The PVC was supplied by Timco Inc., of Sauk Prairie, Wisconsin, and by Monoflex, Inc., of Largo, Florida. Well screen sections consist of Schedule 80 machine-slotted PVC with 0.01-inch-wide openings. Well screen lengths are 10 feet (1991 series wells) or 20 feet (1989 Series wells) for the water table wells and 5 feet (1989 series wells) or 10 feet (1991 series wells) for the deeper wells. Well locations and installation depths are described in the following subsections.

The 1989 and 1991-series wells at each site are identified with a letter prefix, PBM or PBN, where PB indicates the site (i.e., Propellant Burning Ground), M indicates a single monitoring well, and N indicates a group of nested wells. The number 89 indicates the year the well was installed (i.e., 1989). Nested well screen designations A, B, C, and D represent progressively deeper installation intervals. Well designations without a letter suffix (e.g., PBM-89-07) or a well designation with an A suffix (e.g., PBN-89-01A) represent water table wells. The B suffix (e.g., PBN-89-01B) represents an intermediate level well, while the C and D suffixes represent progressively deeper well-screen intervals.

At the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area water table wells with a 20-foot screened interval were constructed with approximately 15 feet of screen below the water table. Water table wells with a 10-foot screened interval were constructed with approximately 7 feet of screen below the water table. The successively deeper B and C well screens are 5 or 10 feet long with the top set approximately 20 to 30 feet below the bottom of the screen above it. The D wells have 5-foot well screens; however, the top is generally set approximately 65 feet below the bottom of the screen above it, and typically just above the bedrock surface.

Water table wells have sandpacks placed in the annular spaces between the well screens and borehole walls or casings. The sandpacks for all wells generally extend 5 feet above the top of the screens. Water table wells have a 5-foot bentonite pellet seal above the sandpack. Type II cement/bentonite grout placed above the pellet seal extends to the ground surface. Intermediate and deeper wells have sandpacks surrounding the well screens that generally extend 5 to 10 feet above the top of the screens. A 5-foot bentonite slurry was placed over the sandpack before placing the Type II cement/bentonite grout. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated approximately 3 to 4 feet into the ground. A coarse 1- to 1.5-inch stone blanket (6 or more inches thick) was placed around each protective casing.

Well installation diagrams with associated boring logs are in Appendix D. Grout was allowed to set for a minimum of 48 hours before the wells were developed. Well development was accomplished with a submersible pump raised and lowered across the screened section of the well. A minimum of five well volumes of water was removed during the development process. During some well installations, it was necessary to add water to reduce the effect of sand entering the drill casing. In these cases volume estimated to be equal to three times the water added during drilling was removed in addition to the five well volumes. Appendix D contains records of well development activities.

6.2.7 Borehole Geophysics

A geophysical logging program was conducted at BAAP by Colog, Inc. (Colog), of Golden, Colorado, under the coordination and supervision of ABB-ES. The purpose of this program was to further investigate and characterize subsurface geology. This was undertaken to support geologic findings which were based on disturbed soil cuttings obtained from the dual-wall driven-casing drilling technique. Generally, the geologic findings from the borehole cuttings correlated with the borehole geophysics results. This program consisted of field geophysical logging and data interpretation of 18 PVC-cased monitoring wells with depths of 90 to 240 feet. The monitoring wells logged at the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area consisted of wells drilled with HSAs and dual-wall reverse circulation in 1989, and wells drilled with mud rotary in 1982. Construction diagrams for these wells are in Appendix D. Table 6-4 summarizes each monitoring well logged during the borehole geophysical program.

The logging suite consisted of natural gamma, non-focused gamma-gamma density, dual gamma-gamma density, neutron, and induction. Additionally, a single-arm caliper log of the casing was collected with the dual-density measurement. Logging methods, field operation procedures, quality assurance (QA), log processing, and log interpretation are described in Appendix E. For each well, log measurements were analyzed with respect to geologic sample descriptions from the drilling log and borehole completion descriptions.

Borehole geophysical logging equipment included a Model 2500 and an EM-39, manufactured by EG&G Mt. Sopris Instrument Company and by Geonics Limited, respectively. All data were collected digitally with Colog's data acquisition system and a portable personal computer. Subsequent processing and display of the data were completed with Colog software. All data were collected at 0.5-foot intervals, except for induction data, which were collected at 0.2-foot intervals and then processed with appropriate equations to 0.5-foot intervals.

Radioactive logging probes were lowered to the bottom of each well; digital and analog records were made as the probe was brought to the surface. The induction logging probe was recorded when lowered in the well and when pulled back to the surface. Analog data were used on site to ensure the probes operated correctly. Digital data were processed and graphically presented and used for the interpretation. Logs from the different probes were aligned at a common elevation and scale for composite presentation in the interpretation.

The logs are used to assist in determining site geology and lithology in the well bore and to identify anomalies reflecting well construction imperfections, such as voids or gaps in the grout behind the well casing. Quantification of formation density and porosity was examined from the log data. However, the presence of grout materials in the well bore resulted in only bulk approximations of these parameters. Hydrogeologic information such as fluid saturation was also inferred from the logs and correlated with geological description in the boring logs.

6.2.8 Permeability Testing

To obtain an estimate of permeability variations within the unconsolidated aquifer at the site, a series of rising-head slug tests was performed on 23 new and six existing shallow and deep monitoring wells within the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area. Water displacement for the tests was accomplished by pressurizing the well casing of piezometers screened entirely below the water table and physical displacement of water with a cylindrical slug for monitoring wells with screens intersecting the water table. At the deep monitoring wells, the water column was typically depressed from 2 to 9 feet by sealing the well casing at the wellhead and pressurizing the well with compressed breathing air. Precautions were taken to ensure that air was not forced into the aquifer by lowering the water level into the screened interval of the well. The water level was allowed to return to a static condition after releasing the air pressure. At shallow monitoring wells, the water column was displaced with a 2-inch diameter cylinder which was lowered 5 to 8 feet below the static water level. After allowing the water level to recover to its static condition, the slug was quickly withdrawn. As the water rose to its static level, data was gathered for the rising-head test.

The rate of water level rise was recorded with a 20-psi (pounds per square inch) pressure transducer and Hermit 2000 data logger, both supplied by In-situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which can result in water level rebound above the static background level where hydraulic conductivities are high.

Generally, two to five tests were performed on each well to assess the variations associated with each test, evaluate the inertial effects associated with each well, and apply the maximum stress possible at each well. The test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected tests were also analyzed by the Bouwer and Rice (1976) technique (see Appendix I). Results of the Bouwer and

Rice analyses compared favorably with Hvorslev results. Results of the Hvorslev analyses are summarized and discussed in Subsection 6.3.3.

6.2.9 Aquifer Pumping Test

In December 1991, an aquifer pumping test was performed by ABB-ES at the IRM extraction well BCW-3 in the southern area of the Propellant Burning Ground (Figure 6-12). The purpose of the test was to provide an additional estimate of the hydraulic properties of the sand and gravel aquifer beneath BAAP. An aquifer test report, detailing specifics of the test, is included in Appendix J. The IRM facility consists of a groundwater extraction and treatment facility for intercepting and stripping contaminated groundwater of VOCs and SVOCs.

Extraction wells BCW-1, BCW-2, and BCW-3 were shut down on December 5, 1991, to allow water level recovery to static conditions. On December 7, 1991, the 100-gpm pump was removed from BCW-3 and replaced by a 250-gpm pump. An increased pumping rate was necessary to increase the stress to the aquifer, to allow a better assessment of hydraulic characteristics of the aquifer than provided by permeability (slug) testing.

An in-line, totalizing flow meter (manufactured by McCrometer of Hemet, California) was installed in the BCW-3 discharge line near the wellhead to accurately measure the pumping discharge (flow) rate. Flow meters available in the IRM treatment facility building were used as a backup for flow rate measurements. During the aquifer test, water from BCW-3 was piped through the existing collection system to the IRM treatment facility and treated before discharge to the Wisconsin River.

To monitor recovery of water levels after shutdown of the BCW-series wells, and to evaluate antecedent (prior to the start of pumping at BCW-3) water level trends, pressure transducers were installed in piezometers and monitoring wells near BCW-3 before the start of the test. Before installation of these pressure transducers, water level measurements were taken from each well to an accuracy of one hundredth of a foot with a SOLINST™ electronic water level meter. The transducers were connected to Hermit™ data logging instruments for automated recording of water levels every hour. Piezometers and wells monitored by the data loggers were PBP-91-01B,C,D, PBP-91-02B,C,D, PBN-91-06C,D, and BCW-3 (Figure 6-12).

Water levels in monitoring well S1123, located northwest of the Propellant Burning Ground, were also monitored with a pressure transducer to evaluate regional water table fluctuations before, during, and after the constant-discharge test. In addition, manual water level measurements were taken at the following wells to assist in measuring the cone of depression caused by the pumping test: PBN-85-04A, PBN-89-04B,C, PBM-85-05, PBM-85-06, PBM-89-07, PBN-89-12A,B, and PBN-91-12C,D (see Subappendix A of Appendix J.1 for water level data sheets). The locations of these observation points are illustrated in Figure 6-12.

The constant-discharge test was started on December 11, 1991, at 4:00 p.m. (1600 hours). The average flow rate over the 24.5 hour test was 205 gpm. Analysis of the test data indicates a calculated transmissivity from 196,000 to 314,000 gpd/ft. (Table 6-5). The range for the averages of the three methods used to analyze the data is from 236,000 to 273,000 gpd/ft. (see Table 6-5). In general, the B- and D-series wells exhibited higher values of transmissivity than the C-series wells. This implies that the horizontal hydraulic conductivity is greater for these zones, which is supported by boring log data that indicates the presence of gravel layers in the B and D zones (approximate depth interval).

Storativity values from the two analytical methods used for analysis of drawdown data range from 0.04 to 0.14, with a range between the averages of the two methods of 0.09 to 0.11 (see Table 6-5). These values fall within the range of 0.01 to 0.3 for unconfined aquifers given by Driscoll (1986), but are slightly lower than expected for the relatively coarse sand and gravel aquifer beneath BAAP.

Assuming unconfined conditions in the aquifer, the theoretical specific capacity of pumping well BCW-3 is 170 gpm/ft of drawdown while the actual specific capacity measured at the well is 19.6 gpm/ft of drawdown. The well efficiency can be computed by dividing the actual specific capacity by the theoretical specific capacity: the result is 12 percent. This low efficiency is probably caused by several factors potentially including improper well installation and development, and biologic plugging of the screen. A large amount of iron bacteria was observed on the drop pipe when the 100-gpm pump was pulled from BCW-3 prior to the start of the test.

Although the calculated well efficiency for BCW-3 is low, the analyses of the data and the hydraulic aquifer parameter estimates obtained from the analyses is not affected because all parameter estimates were based on drawdown measurements in the nearby monitoring wells and piezometers.

The Draft Aquifer Test Report was given a cursory review by the WDNR following its delivery on May 19, 1992.

6.2.10 Groundwater Sampling

Two separate groundwater sampling episodes were undertaken by ABB-ES at BAAP. In September and October of 1990, two limited rounds of groundwater samples (1990 Round I and 1990 Round II) were collected from selected wells (PBN-89-04B,C and SPN-89-03B,C) in the Propellant Burning Ground and along the southern base boundary, south of the Settling Ponds. Samples were collected from the four monitoring wells and analyzed by DataChem Laboratories for the following VOCs: 11DCE, 11DCLE (Round II only), 12DCE, 12DCLE (Round II only), CCL4, CHCL3, and TRCLE. Only select VOCs were analyzed in an attempt to more clearly define the off-post VOC plume. Two complete rounds of groundwater samples were collected in November and December of 1991 (Round One) and April and May of 1992 (Round Two) from monitoring wells located in the Propellant Burning Ground, Landfill 1, and Settling Ponds Areas (Table 6-6). Arthur D. Little, Inc., performed the analyses of the groundwater samples from Rounds One and Two. *Round One was conducted following the installation and development of the 1991-*series monitoring wells. Wells S1101, S1145, S1146, and PBN-82-04A did not contain adequate water to allow for sampling of proposed analytes. Locations of sampled wells are shown in Figure 6-11.

The specific groundwater sampling procedures followed are described in the BAAP RI Sampling Design Plan developed by ABB-ES, reviewed and accepted by USATHAMA, WDNR, and USEPA (E.C. Jordan Co., 1989 and 1990c; ABB-ES, 1991).

Water level measurements to the nearest 0.01 foot were obtained at each well during each sampling round using an electronic water level meter. Water level data are in Appendix G and discussed in Subsection 6.3.3. After water level measurement and before sampling, each well was purged with a submersible pump. Purge volumes varied depending on the standing volume of water in the well casing. Generally, five times the sandpack and well volume were purged before sampling. Variances were documented and recorded on field data sheets found in Appendix G. Purge water and groundwater samples were monitored in the field at the time of collection for temperature, pH, and specific conductance. Purge water from 28 wells suspected of having VOC or DNT concentrations exceeding WDNR health criteria were collected and discharged to the installation WWTP, as directed by WDNR. Groundwater field sampling data are summarized in Appendix G.

Round One and Round Two groundwater samples were shipped to A. D. Little, Inc., for the various analyses specific to each site. Decontamination of field sampling equipment was accomplished by steam-cleaning with water from Production Well No. 2.

6.2.11 Summary of Chemical Analysis Schedule

The following subsections summarize the chemical analysis schedule.

6.2.11.1 Laboratory Analytical Program. Three laboratory contractors participated in the BAAP RI analytical program: EA Laboratories, of Sparks, Maryland; DataChem Laboratories, of Salt Lake City, Utah; and A.D. Little Laboratories, of Cambridge, Massachusetts. Soil, sediment, and surface water samples were analyzed by DataChem and EA. DataChem also analyzed groundwater samples from Round I (September 1990) and Round II (October 1990). A.D. Little analyzed groundwater samples from Round One (November/December 1991) and Round Two (April/May 1992).

Soil and sediment samples were collected by ABB-ES personnel during the fall of 1991. Surface soil and sediment, and subsurface soil samples were analyzed for organic and inorganic chemicals listed in Tables 6-7 and 6-8, respectively. Groundwater samples collected by ABB-ES were analyzed for the organic and inorganic chemicals listed in Table 6-9. Discrepancies between analyses proposed on samples in the Sampling Design Plan (Data Item A009) and analyses actually performed are summarized as follows:

- Surface soil samples at the Propellant Burning Ground: the locations of samples where TCLP metals and SVOCs (BN/As) were to be analyzed differed from those proposed in the Sampling Design Plan. This discrepancy is a result of a change made in the sampling design grid at the request of the USEPA immediately prior to field work.

- Subsurface soils from the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area: the number of analytical samples obtained from some borings differed from the proposed number. Increases were due to the need for additional samples based on field observations, while decreases were often due to poor split spoon sample recovery.

- Groundwater samples: some monitoring wells recharged at very slow rates which precluded collection of some samples. This includes monitoring wells S1101, S1145, and S1147.

ABB-ES' analytical subcontractors A. D. Little, EA, and DataChem used procedures consistent with the USATHAMA Contract Laboratory Analytical Services Support (CLASS) program for analysis of groundwater, soil, surface water, and sediment samples. A list of chemical analytical methods used by each laboratory are presented in Appendix L. Analytical methods are described in Section 4.0 of the Sampling Design Plan. Several general water quality parameters (e.g., HARD, total ALK, and TDS) did not require certification under the USATHAMA program.

Reference information on the basis of USATHAMA methodology is contained in Appendix L. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings with certified detection limits.

The analyte matrix is based on the soil and water chemical data presented in the MEP and the substances reportedly burned and disposed of at the three sites (Tsai et al., 1988). Because of the potential for elevated metals to limit disposal options for soils at these locations, selected samples were submitted for analysis of TCLP extractable PB, CD, CR, and HG. Results of the TCLP analyses being promulgated for evaluation of toxicity as a component of RCRA (40 CFR 268.7 Appendix I), will be used in this report for estimating the leachable metal concentrations from soil samples.

6.2.11.2 Field Testing. During the purging of each well, field measurements of specific conductance, temperature, and pH were taken. These data can be found on the Groundwater Field Data sheets in Appendix G.

6.2.11.3 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data and the geotechnical data from the field drilling program.

For each well sampled, a Groundwater Field Data Record sheet (see Appendix G) was completed. This sheet contains specific information on each well. Information such as the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, and sampling technique is recorded. A field notes section provides for any additional site information sampling personnel may need to include. Each well has a Monitoring Well Installation Data Record that documents structural details.

When soil samples were taken from test borings, a Field Boring Log was completed. On this log, the driller and geologist record notes from the soil sampling event. The Field Boring Log and the field notes are both kept on file by ABB-ES. Samples were given unique site IDs for identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data was entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both ABB-ES' home office and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map Files, Geophysical Groundwater Stabilized Files, Geophysical Field Drilling Files, Geotechnical Well Construction Files, Chemical Groundwater Files, Chemical Surface Water Files, Chemical Soil Files, and Chemical Sediment Files.

Chain of custody records along with analytical request forms (ARFs) were used to coordinate transfer of samples from field sampling locations to the laboratory. Samples were further divided by the laboratories into sample lots according to method, matrix, and analytical QC groups.

6.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area are located in the southern portion of BAAP and share similar geologic and hydrogeologic settings. These areas are discussed together in the following subsections.

6.3.1 Surface Water Hydrology

The Propellant Burning Ground facilities are approximately 20 acres in size. The Propellant Burning Ground is located on the westward-sloping flank of the terminal moraine in the southwestern portion of BAAP. The Settling Ponds and Spoils

Disposal Area consists of a series of four man-made depressions (Settling Ponds) and five dredged soil disposal sites (Spoils Disposal Area). These ponds are oriented roughly parallel and adjacent to the southern boundary of BAAP. The Settling Ponds appear to occupy a former stream channel of the Wisconsin River (Socha, 1984). The Settling Ponds and Spoils Disposal Area occupies approximately 90 to 100 acres with approximately 40 acres devoted to the Settling Ponds.

Topographic relief in this area is largely dominated by the Johnstown terminal moraine ridge, the outwash plain west of the moraine, and the pitted surface east of the moraine. The morainal ridge, rising as much as 60 to 80 feet above the surrounding area, is oriented roughly north-south in the vicinity of the Propellant Burning Ground, but trends more northwest-southeast in the vicinity of the Settling Ponds and Spoils Disposal Area (Figure 1-1). West of the morainal ridge, the ground surface slopes downward at 5 to 10 percent to the outwash plain, where slopes decrease to approximately 2 percent or less. Behind the morainal ridge to the east, the surface relief typically becomes irregular with numerous knobs and kettles and approximately 50 feet of vertical relief. The exception to this condition is in the Settling Ponds area where man-made excavations of a former stream channel have created the series of Settling Ponds that drop to the east and eventually lead to Gruber's Grove Bay on Lake Wisconsin.

Surface water runoff in the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area is restricted to ephemeral flows of spring runoff following snowmelt. Much surface runoff that does occur is captured in isolated depressions and then evaporates or infiltrates. This is particularly true east of the morainal ridge. The morainal ridge forms a surface water divide forcing a portion of runoff to flow westward toward the outwash plain (where it may drain into Final Creek), and the remainder to flow eastward into poorly defined drainage patterns. Final Creek routes surface water runoff and wastewater from the WWTP to the east for discharge into the Settling Ponds (see Figure 6-3). During periods of large-scale propellant production before the mid-1970s, sanitary wastewater which had undergone primary treatment and partially treated (neutralized) industrial wastewater flowed into Final Creek and filled the Settling Ponds before discharging to the Wisconsin River at Gruber's Grove Bay on the Lake Wisconsin Reservoir. Since the completion of the WWTP in 1970s, wastewater has been treated before discharge to the ponds. However, when BAAP is not in operation, there is no discharge to the river except surface runoff under extreme snowmelt conditions.

6.3.2 Geology

Soil borings and monitoring wells installed at the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area encountered soil conditions consistent with those observed at other BAAP locations. This includes approximately 250 feet of unconsolidated soil deposited in association with the maximum advance of the Green Bay Lobe Glacier (Alden, 1918; and Thwaites, 1958).

Generally, the stratigraphic sequence includes a veneer of fine-grained silt underlain by variably textured sands and gravels with occasional cobble and boulder zones. At an approximate elevation of 700 to 725 feet MSL, a continuous 10- to 20-foot-thick cobble and gravel layer (oriented north-south) was encountered. This coarse layer appears to be located west of and parallel to the axis of the terminal moraine. Underlying the cobble and gravel layer are additional deposits of variably-textured sands and gravel. Immediately above bedrock, another gravel cobble layer was encountered. Finally, sandstone bedrock belonging to the Eau Claire Formation was encountered at an approximate elevation of 600 to 620 feet MSL. The bedrock appears to have a relatively flat surface with a gentle slope to the southeast (see Figure 2-2).

Geologic cross sections depicting generalized stratigraphic relationships among the various soil units at the site are oriented in Figure 6-13 and shown in Figures 6-14, 6-15, and 6-16.

Immediately below the ground surface under both the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area is a 5- to 10-foot-thick veneer of loess. This fine-grained unit consists of windblown silt and clay. Logs of borings drilled in this area generally describe this unit as a cohesive silt and clay with some interbedded fine sand at depth. While most borings installed with HSAs at the Propellant Burning Ground indicated the presence of loess, it appears likely that loess materials were stripped from the burning pits and Waste Pits. Borings installed with dual-walled driven casing techniques often identified a very thin or absent loess unit. It is probable that the high pressures associated with this drilling technique forced the loess materials away from the casing while penetrating this near-surface unit.

Borings installed during 1981 within Settling Pond 1 indicated several feet of recent alluvium or sediment that has collected over the loess (Warzyn, 1982a). This material was probably transported from Final Creek. However, Settling Ponds 2 and 3 appear to have a coarse granular base with no loess deposits. This condition likely reflects either the lack of sedimentation in these lower ponds or the removal of loess materials during dredging operations or fluvial erosion. Given the regional extent of the loess unit, it is likely this unit extends south of the Settling Ponds and Spoils Disposal Area.

Variably textured sands and gravels were encountered beneath the surficial loess materials. These were typically characterized as ranging from brown, fine-to-coarse sand with a trace of silt and fine gravel, to light brown, medium-to-coarse gravel with little sand. No substantial silty or clayey tills were encountered in the borings installed during 1989 at the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area.

A continuous, nearly flat lying, 10- to 20-foot-thick coarse-grained cobble and gravel layer was encountered at an approximate elevation of 700 to 725 feet MSL west of the terminal moraine in the Propellant Burning Ground. The texture and location of this coarse-grained unit suggest it might represent erosion and initial outwash deposition during the period of maximum glacial advance. This coarse-grained unit is laterally extensive along the western boundary of the terminal moraine and could extend to the Baraboo Hills north of BAAP parallel to the terminal moraine. Boring logs from monitoring wells off-post south of BAAP indicate that this unit extends to the Town of Prairie du Sac south of BAAP. Numerous, very dense cobble and boulder zones were encountered at higher elevations within the unsaturated zone in borings drilled near the axis of the morainal ridge.

Recent research conducted on soil deposits associated with the Johnstown Moraine in Sauk County have identified four separate soil units typically encountered within the terminal moraine deposits (Clayton, 1989). The research is based on soil deposits exposed at a series of gravel pits along the moraine in this region. As such, the research focuses on depositional conditions within the upper 30 to 60 feet of the moraine. The units typically identified from the deepest layer up include (1) a basal stratified outwash deposit encountered at the base of the moraine, (2) esker deposits containing coarse gravel, (3) a stratified diamicton (non-sorted or poorly sorted, nonlithified geologic deposit) that possibly represents a reworked glacial till, and (4) an inhomogeneous coarse-grained deposit, which is poorly stratified and may represent a washed supraglacial till. Supraglacial till is composed of glacial materials deposited by melting out of glacial ice. Supraglacial till typically has fewer fines, greater stratification, and a lower density than a basal till.

Bedrock was encountered in soil boring PBB-89-10 (240 feet), BAAP Production Well No. 5 (260 feet), and SPN-91-03D (225 feet). The bedrock was described as a white to light brown, fine-to-medium sandstone, which is very dense and has a poorly cemented upper surface. However, substantial siltstone and shale units were also observed with depth. The bedrock likely belongs to the Eau Claire Formation (Upper Cambrian). The bedrock surface elevation is approximately 615 to 620 feet MSL at the Propellant Burning Ground and, as shown in Figure 2-2, appears to dip gently downward to the southeast.

6.3.3 Hydrogeology of Unconsolidated Sediments

Hydrogeologic conditions at the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area are discussed in this section. A summary of area-wide conditions followed by more detailed descriptions of recharge rates, the influence of the Lake Wisconsin WP&L dam on the groundwater flow system, vertical and horizontal gradients, aquifer testing, and hydraulic conductivity testing are included. As with other locations at BAAP, hydrogeologic conditions at the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area are controlled mainly by geologic conditions underlying the area. Hydrogeologic conditions are also influenced by the elevated water level in the Lake Wisconsin Reservoir and the lower water level below the WP&L dam.

A 5- to 10-foot-thick layer of silty clayey loess underlies the topsoil in this area. Laboratory permeability tests conducted on soil samples collected from this unit indicate its low permeability (Warzyn, 1982a). Laboratory hydraulic conductivities of $4x10^{-7}$ and $5x10^{-6}$ cm/sec, respectively, were reported for subsurface soil samples from PBN-82-01A and PBN-82-02A, collected at depths of 4 to 6 feet and 2.5 to 4.5 feet. As described in Subsection 2.2.3, the near-surface fine-grained loess unit restricts the deep infiltration of precipitation to approximately 5 to 9 inches per year. Below the loess, a thick sequence of sand and gravel comprises a 100 to 150 foot thick vadose zone through which groundwater percolates before recharging the water table. The water table is located as deep as 140 to 150 feet bgs at Landfill 1, and as the ground surface slopes downward to the southeast near the Wisconsin River, depth to the water table is decreased to approximately 40 feet bgs. West of the terminal moraine in the areas of the Propellant Burning Ground and southwestern corner of BAAP, the depth to the water table is approximately 50 to 75 feet bgs.

The water table at the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area occurs in coarse-grained sands and gravels, resulting in relatively small vertical gradients and uniform horizontal gradients across the water table. Vertical gradients calculated at various well nests at the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area are described in Table 6-10 and illustrated in Figures 6-14, 6-15, and 6-16. Gradient calculations are in Appendix H. Table 6-10 identifies both upward and downward gradients, which tend to be fairly small across this area. Localized variations in the gradients likely reflect changes in hydraulic conductivity and flow velocities in the groundwater flow system. However, the gradients could reflect substantial flow in the deep gravel/cobble layer. Several well nests have shown downward gradients from the upper portion of the sand and gravel aquifer into the gravel/cobble zone (i.e., PBN-85-03A/PBN-89-03B, PBN-85-04A/PBN-89-04B, PBN-89-12A/PBN-89-12B, and S1147/SPN-89-03B). Several other well nests have shown upward gradients into the gravel/cobble zone from the lower portion of the sand and gravel aquifer (i.e., PBN-89-10B/PBN-89-10C and PBN-89-03B/PBN-89-03C). This gradient pattern could reflect the gravel zone acting as a hydraulic drain and inducing small vertical flow components that are upward from below and downward from above in the less permeable sands. This condition is not reflected in all well nests; well nest PBN-89-12B/PBN-89-12C has a downward vertical gradient indicating flow out of the gravel/cobble zone into a deeper portion of the aquifer.

Horizontal gradients measured between selected water table wells are described in Table 6-11; gradient calculations are in Appendix H. Table 6-11 indicates that horizontal gradients are relatively small and uniform (i.e., 0.0013 to 0.0015 feet per foot [ft/ft]) across the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area. This condition is typical of sand and gravel aquifers where highly permeable subsurface soil is not capable of supporting strong gradients.

Hydraulic conductivity tests (in situ rising-head slug tests) were completed by ABB-ES in 29 wells at the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area. In addition, Warzyn had previously conducted a series of laboratory permeability tests (Warzyn, 1982a). Results from the ABB-ES tests are summarized in Table 6-12, with detailed analyses presented in Appendix I. The tests conducted by ABB-ES focused on the shallow and deep monitoring wells, and indicate a hydraulic conductivity range of 1×10^{-3} to 2×10^{-1} cm/sec, with a median value of 4×10^{-2} cm/sec. These results correlate well with aquifer test results from Boundary Control Wells No. 2 (BCW-2) and No. 3 (BCW-3), which indicates a conductivity of 2×10^{-2} to 8.5×10^{-2} cm/sec (see Appendices H and I for analysis), as well as the specific capacity test performed on BAAP Production Well No. 4, which indicated a hydraulic conductivity of 5×10^{-2} cm/sec.

Results of in situ hydraulic conductivity tests conducted by ABB-ES generally indicate higher hydraulic conductivity than the laboratory or in situ test results generated by Warzyn (from 1980 to 1982). Laboratory tests often give results differing from field tests as they tend to reflect vertical hydraulic conductivities, which are typically lower than horizontal hydraulic conductivities reflected by in-situ tests. In addition, most Warzyn tests were completed on soil samples collected above the water table and may reflect finer grained, lower permeability soil deposits.

Hydraulic conductivity tests performed in wells screened in the gravel/cobble layer (encountered at an approximate elevation of 700 to 725 feet MSL in borings located just west of the axis of the terminal moraine) have shown evidence of a high permeability zone. The higher hydraulic conductivity is illustrated by test results at wells LON-89-02B (K = 4x10^{-2} cm/sec), PBN-89-10B (K = 2x10^{-1} cm/sec), and PBN-89-01B (K = 3x10^{-2} cm/sec). The horizontal gradient along this unit is relatively uniform at 0.0012 to 0.0015 ft/ft, agreeing with the data from the water table wells in this area (see Appendix H). Given the higher permeabilities and similar horizontal gradients, it is likely that groundwater flow velocities and discharge rates are higher in the gravel/cobble layer than in the adjacent sandy soil. As shown in Figure 6-14, vertical gradients often indicate flow into the gravel/cobble layer from above and below. These conditions make the gravel/cobble layer a likely preferred flow path in the south-central area of BAAP.

6.3.4 Groundwater Movement

Horizontal and vertical groundwater flow gradients and directions are generally uniform over the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area. Vertical gradients within the unconsolidated soil generally are small with a tendency for groundwater to flow into the cobble/gravel zone, as discussed. However, upward vertical gradients from the bedrock into the unconsolidated soil are likely significant (Subsection 2.2.3.2).

Figure 6-17, an interpreted water table contour map for the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area, indicates that horizontal flow gradients are uniform and consistent across much of the area, with a total head drop of 10 to 11 feet from the northern Propellant Burning Ground to the installation boundary. Groundwater elevation data is presented in Appendix G. Generally, groundwater flow is south, with a southwesterly flow component in the southeastern portion of the Settling Ponds and Spoils Disposal Area and a minor southeasterly flow component in the northern portion of the Propellant Burning Ground.

The transition of groundwater flow from south-southeasterly in the western portion of the Propellant Burning Ground to south-southwesterly in the eastern portion of the Settling Ponds and Spoils Disposal Area reflects the influence of the elevated water level in the Lake Wisconsin Reservoir east of BAAP. The WP&L dam, located approximately 1.5 miles south of the BAAP boundary has an approximate 40-foot head difference across the dam. The elevated water level in the reservoir forms a gradient that could result in discharge to groundwater from the Lake Wisconsin Reservoir in this area. This occurs near the reservoir where the groundwater elevation in the aquifer is lower than the reservoir elevation (i.e., 774 feet MSL). This condition occurs near the eastern end of the Settling Ponds and Spoils Disposal Area.

Groundwater flow velocity calculations were performed for the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Area. The calculations indicate a velocity range of 30 to 460 feet per year (ft/yr), with an estimated median velocity on the order of 330 ft/yr. The higher velocities are most likely associated with the coarse gravel/cobble zone while the lower velocities reflect conditions in finer-grained sand zones. Calculations and assumptions for these analyses are in Appendix H.

6.3.5 Groundwater Flow Models

In addition to the regional hydrogeologic model discussed in Subsection 2.2, two hydrogeologic models were constructed to assist in the interpretation of groundwater flow in the vicinity of the Propellant Burning Ground and surrounding area. A detailed discussion of all groundwater flow models is presented in Appendix J. A general box model was developed to assess the influence of the sand and gravel layers on vertical groundwater flow. This model helped establish the number of layers needed to simulate groundwater flow in the site-specific Propellant Burning Ground model. Boundary conditions for both models were based upon the BAAP regional groundwater flow model. The site-specific Propellant Burning Ground model was developed to focus on groundwater flow at the Propellant Burning Ground and IRM extraction wells.

6.3.5.1 Conceptual Setting. The modeling effort is based on a conceptual model of the Propellant Burning Ground geologic/hydrogeologic system that consists of an unconfined, isotropic aquifer under steady-state conditions. The aquifer occurs in a thick sequence of highly permeable, unconsolidated glacial deposits overlying sandstone bedrock units with a much lower permeability. The lower permeability of the bedrock unit likely restricts groundwater flow between the bedrock and unconsolidated flow systems. Given this condition and the lack of available information about the bedrock flow system, the modeling efforts do not include the bedrock units as part of the active aquifer. Boundary conditions for the models consist of no-flow boundaries on the eastern and western edges, representing parallel flow lines, and constant-head boundaries on the northern and southern boundaries, representing lines of equal head taken from the BAAP regional groundwater flow model.

6.3.5.2 Data Collection. The data used in the two models were taken from the BAAP regional groundwater model (see Subsection 2.2.3.3). Data from the October 1989 water level elevations and the December 1991 pump test (see Subsection 6.2.9) were used to calibrate the Propellant Burning Ground model.

6.3.5.3 Preprocessor Description. MODELCAD (developed by Geraghty and Miller, Inc.), a graphical interface groundwater model preprocessors was used to assemble the data sets for the USGS Modular Three-Dimensional Finite Difference Groundwater Flow Model Code (MODFLOW) (McDonald and Harbaugh, 1988). This preprocessor enables the user to visually assemble data and easily develop the model grid, boundary conditions, zonation, and parameters.

6.3.5.4 Model Description. The USGS MODFLOW was chosen for both the box and Propellant Burning Ground models. MODFLOW was selected for its ability to simulate three-dimensional aquifer conditions, its flexibility in parameter assignment and acceptability in the modeling community. The USGS particle tracking program MODPATH (Pollock, 1989) was selected for computing the flow lines of the particles. MODPATH works with MODFLOW output to calculate particle position with time.

6.3.5.5 Box Model. A simple box model was created to assess the hydrogeologic interaction of the interbedded sand and gravel layers during the pumping of an extraction well similar to the Boundary Control Wells (BCW-1, 2, and 3). This effort was undertaken to establish the degree to which groundwater flow is or is not dominated by the coarse gravel layers. This analysis was needed to optimize the number of layers assigned to the site-specific Propellant Burning Ground model. A single pumping well, screened in the top sand and gravel layers, was located in the middle of the box. Particle tracking was used to assess groundwater flow between layers.

To avoid difficulties associated with calibrating the storativity in the models, the model was operated at steady-state. Although this does not allow the model to simulate transient conditions, this was not considered a problem as results of the aquifer test indicated the aquifer quickly responded to pumping stress (at 200 gpm) reaching steady-state conditions in a matter of hours.

6.3.5.5.1 Model Parameters

The box model consisted of seven layers, dividing the aquifer above the bedrock into five sand and two gravel layers (Figure 6-18). Layer thicknesses were based upon average depths determined from borings in the area of the Propellant Burning Ground pumping wells. Grid spacing was 50 feet for both rows and columns. The final model consisted of 45 rows and 50 columns (2,250 cells per layer) (Figure 6-19). The box model boundaries consisted of constant-head cells of 772 feet along the northern boundary and 769 feet along the southern boundary, with no-flow boundaries along the eastern and western boundaries. Horizontal conductivity for the sand layers was the same as the regional model (150 ft/day) and horizontal conductivity for the gravel layers was set at 1,500 ft/day to represent a conservative value an order of magnitude higher. Vertical conductivity was set at one-tenth the horizontal conductivity to provide a conservative model. The recharge rate remained the same as for the regional model (6 in./yr). Porosity, required by the MODPATH program, was set at .30. The pumping rate for the well was set at 100 gpm. Particles tracking along groundwater flow lines were input into the north edge of the model for 600 feet on either side of the well. This allowed model simulations to evaluate the approximate influence of the extraction well on the groundwater flow system.

6.3.5.5.2 Calibration

This model was developed to assess the relative interaction between sand and gravel layers, and thereby assist in determining the number of vertical layers needed for the site-specific Propellant Burning Ground Model. This model was used to assess only these relative interactions, and no calibration was required.

6.3.5.5.3 Sensitivity Analysis

Following construction, the box model underwent a sensitivity analysis in which the values of model parameters were independently varied to determine the sensitivity of each parameter within the model. This analysis was conducted by varying horizontal and vertical hydraulic conductivity, recharge, constant-head elevation, and bottom elevation in independent steady-state evaluations. The results of the box model sensitivity analysis are provided in Appendix J.

6.3.5.5.4 Results and Conclusions

Final water table elevations and particle tracking results are provided in Appendix J.

The final box model simulations included conservative hydraulic conductivity values of 1,500 ft/day in the gravel layers and 150 ft/day in the sand layers. The difference in hydraulic conductivity between the two layers is greater than that suggested by the results of the aquifer test. However, results of the box model indicated that the influence of the extraction well (pumping at 100 gpm) extended through the high hydraulic conductivity gravel zone and into the lower hydraulic conductivity underlying sand layers. These results indicate that groundwater flow, particularly to extraction wells, is not completely dominated by the presence of coarse-grained gravel layers. The influence of extraction wells can extend through the coarser grained layers. This conclusion is supported by the results of the box model sensitivity analysis and aquifer test results.

6.3.5.6 Propellant Burning Ground Model. The Propellant Burning Ground model was developed to allow detailed assessments of groundwater flow. Within the RI, the model simulates existing site conditions. This includes all four IRM wells pumping at their existing rates as well as the December 1991 BCW-3 aquifer test. During the FS the model will be used to enhance evaluation of alternate pumping scenarios.

6.3.5.6.1 Model Parameters

The Propellant Burning Ground model includes the Propellant Burning Ground site and an area 9,000 feet to the south and 1,000 feet to the east and 1,000 feet west. The study area was approximately 10,125 feet long by 7,250 feet wide (Figure 6-20). Groundwater flow is generally southward across the site with a head drop of approximately 13 feet across the site (gradient equals 0.0013 ft/ft).

Geologic conditions in the Propellant Burning Ground model consisted of five layers, representing three sand and two gravel units in the overburden aquifer. These were modeled with five separate layers (Figure 6-21). Layer thickness and bedrock elevations were based upon borings completed at the Propellant Burning Ground wells.

The Propellant Burning Ground model boundaries consisted of constant-head cells of 776 feet along the northern boundary and 763 feet at the southern boundary, with no-flow boundaries along the eastern and western boundaries. Initial parameter input values were the same as the box model (K=150 ft/day for the sand layers and K=1,500 ft/day for the gravel layers). Vertical conductivity for each layer was again 10 times less than the horizontal conductivity. The recharge rate remained the same as the regional model (6 inches/yr). Porosity for the particle tracking program was set at 0.30.

Once basic site parameters were quantified, a base map was constructed with MODELCAD. A grid with spacing of 250 feet for both rows and columns was superimposed on the map. To refine model results in the area of the IRM pumping wells, the grid density was increased by narrowing the cell width to 50 feet in the area around the IRM pumping wells. South of the pumping wells the cell length was set at 125 feet (see Figure 6-20). The final grid consisted of 80 rows and 60 columns (4,800 cells per layer).

6.3.5.6.2 Model Calibration

The Propellant Burning Ground model was first calibrated by approximating the conditions from the regional model and adjusting them to provide a reasonable fit to the known average conditions.

The Propellant Burning Ground model was then calibrated by comparing the head output by the model to values collected from monitoring wells on October 25, 1989. This date was chosen because it was used to calibrate the regional model. The average difference for cells used in the calibration is approximately 0.5 foot (see Appendix J).

As a further calibration, the model was run with parameters to simulate the aquifer test (See Appendix J.1). IRM extraction well BCW-3 was pumped at 200 GPM with BCW-1 and BCW-2 turned off. The horizontal hydraulic conductivity of the overburden sand and gravel layers were set at 195 and 240 ft/day, respectively.

For the final calibration the following parameters were applied:

Horizontal Hydraulic Conductivity in sand layers: 195 ft/day
Horizontal Hydraulic Conductivity in gravel layers: 240 ft/day
Northern Constant-Head cells: 776.0 feet
Southern Constant-Head Cells: 761.5 feet
Horizontal/Vertical Anisotropy Ratio: 3:1
Recharge: 6 inches/year

6.3.5.6.3 Sensitivity Analysis

Following calibration, the Propellant Burning Ground model underwent a sensitivity analysis in which the values of model parameters were independently varied to determine the sensitivity of each parameter within the model. This analysis was conducted by varying vertical and horizontal hydraulic conductivity, recharge, constant-head elevation, and bottom elevation in independent steady-state simulations. The results of the Propellant Burning Ground model sensitivity analysis are contained in Appendix J. Model response to variation in each of the five parameters was analyzed by comparing the water level change in each cell as each parameter was varied above and below its calibrated value. The Propellant Burning Ground model was most sensitive to changes in constant-head boundary elevations over the range of parameters analyzed. The model demonstrated only moderate sensitivity to variation in the other model parameters.

6.3.5.6.4 Results and Conclusions

Two three-dimensional, numerical groundwater flow models simulating the conditions in the Propellant Burning Ground have been developed and calibrated. The modeled heads, flow directions and gradients match well with water level elevations measured in the field. Mass balance within the model as well as that measured between the model and field conditions correlate.

The sensitivity analyses performed on the models indicate that the model is most sensitive to changes in the constant-head boundary elevations. Changing the other parameters caused slight variations in head, primarily at the interior cells.

The box model is useful in understanding the interaction between the sand and gravel layers of the aquifer. The gravel layers do not appear to dominate groundwater flow, even using a gravel hydraulic conductivity one order of magnitude higher than the sand layer. The box model also served as the basis for establishing layers in the Propellant Burning Ground model.

The Propellant Burning Ground model indicates that the current IRM extraction wells are partially effective at capturing the Propellant Burning Ground groundwater contaminant plume. Based on particle tracking at the current pumping rate, the model shows the IRM extraction wells to have a horizontal capture zone of approximately 100 feet in the top sand layer (layer 1) and a horizontal capture zone of approximately 50 feet in the top gravel layer (layer 2). In the second sand layer (layer 3), the capture zone is approximately 25 feet. In layers 4 and 5, no particles are captured. However, the flow line particles are drawn closer together. This site-specific modeling effort indicates that contaminated groundwater is flowing past the IRM extraction wells. Final water table elevations and particle tracking are contained in Appendix J. Figure 6-22 presents the modeled water table contours.

6.4 NATURE AND EXTENT OF CONTAMINATION

6.4.1 Introduction

The contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in soil, sediments, surface water, and groundwater at BAAP. Chemicals that represent site-related contamination were identified based on comparisons of soil, groundwater, and surface water analytical results to background concentrations and, for groundwater WPALs and WESs; frequency of occurrence and concentrations of each chemical; and the relationship of chemicals to past activities.

The contamination assessment is divided into two major segments, contaminant distributions within the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area, and a discussion of the environmental fate and transport of principal chemicals. Discussion of contaminant distribution within each media is presented as a semi-qualitative summary of contamination followed by a more detailed discussion of contaminant distribution.

The primary data used in this report are the results of chemical analyses of soil and water samples collected at the three sites since August 1990,. Analytical results from subsurface and surface soil samples collected at the Propellant Burning Ground, Landfill 1, and Final Creek are used to characterize contaminants and to identify possible source areas. This is supplemented with surface and subsurface soil analytical data developed by Ayres Associates, 1984, for samples collected in the Settling Ponds and Spoils Disposal Area.

Data collected before January 1988 were summarized in the MEP (Tsai et al., 1988). These data contained inconsistencies because of the use of differing analytical methods, sampling techniques, and protocols. These data are used in this report to augment the description of contaminant nature, distribution, and behavior.

Within each section of the contamination assessment, results of chemical analyses are presented by medium. Summary tables listing detected chemicals are included in each section. Results of soil analyses are generally compared to site-specific and regional background data. Chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). Indicator parameters (measured in groundwater samples) are nonspecific measurements that generally characterize water quality. The indicator parameters measured in this program were HARD, ALK, and TDS. These parameters are used, where appropriate, to assist in site-specific data interpretation. Chemical-specific numerical standards and criteria used to evaluate groundwater data are listed in Table 3-4, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WESs, and WPALs. Chemical data tables downloaded from the IRDMIS are contained in Appendix J. Appendix L details specific results of the data quality assessment. This includes (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, (2) a listing of the USATHAMA-certified analytical methods used by the subcontractor laboratories, (3) a summary of the laboratory quality control sample results and impact on associated field samples results, (4) a summary of nontarget, library searched VOC and SVOC compounds detected in the RI analytical program, and (5) a summary of the USATHAMA-approved laboratory control charts.

At the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Areas, 1,1,1-trichloroethane (111TCE), 24DNT, 26DNT, C6H6, CCL4, CHCL3, NC, NNDPA, PB, and TRCLE were the most prominent chemicals observed. The highest concentrations of PB and NC were detected primarily in surface soils at the Propellant Burning Ground and Settling Ponds, respectively. The highest concentrations of DNTs, C6H6, NNDPA, and TRCLE were detected in subsurface soils at the Propellant Burning Ground. No 111TCE, CCL4, or CHCL3 source was identified in the soil to explain the presence of these compounds in groundwater. However, results of the passive soil gas vapor survey indicate the ubiquitous presence of CCL4 vapor in the subsurface soils of the Racetrack Area, and sporadic detects in and north of the Contaminated Waste Area. Groundwater data indicate extensive plumes of CCL4, CHCL3, and TRCLE, with smaller, less well-defined plumes of 111TCE and 26DNT.

6.4.2 Contamination Assessment

The Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area are discussed together because the Settling Ponds and Spoils Disposal Area is located downgradient of the Propellant Burning Ground. Data collected from wells in the vicinity of the Settling Ponds are important for interpreting contaminant migration pathways from the Propellant Burning Ground. Organic and inorganic chemicals related to site operations were detected at the Propellant Burning Ground in soils and groundwater. Inorganic chemicals related to site operations were detected in sediment/surface soil samples collected from the Settling Ponds and Spoils Disposal Areas. In general, results of the analyses by ABB-ES are consistent with less extensive data from previous investigations summarized in the MEP (Tsai, et al., 1988).

6.4.2.1 Soil Vapor Survey. A passive soil vapor survey was performed in the Contaminated Waste Area and Racetrack Areas of the Propellant Burning Ground to aid in the selection of sampling locations (see Subsection 6.2.2 and Appendix B). The results were quantified as ion counts which reflect the relative flux of the contaminants being measured rather than the actual concentrations. As such, a high flux may reflect placement of a probe in a permeable flow path rather than close proximity to source materials. Generally, survey results indicate the presence of aromatic hydrocarbons and chlorinated hydrocarbons throughout the Propellant

Burning Ground. However, the strongest responses were observed in the vicinity of the contaminated Waste Pits, as indicated on the figures presented in Appendix B. The distribution of responses for TRCLE, TCLEE, and simple aromatics is highest in the vicinity of the contaminated Waste Pits located north of the Racetrack. The greatest responses for CCL4 were in the central area of the Racetrack in the vicinity of the Burning Pads and Plates. The responses for CCL4 in the Contaminated Waste Area are much less than those for TRCLE. However, the presence of VOCs was not confirmed in laboratory analyses of surface soil from these locations. Finally, hydrocarbons were detected over much of the Racetrack and Contaminated Waste Areas; however, the highest responses were again observed near the Waste Pits in the Contaminated Waste Area. Figures indicating the distribution of the relative responses are in Appendix B.

To summarize, both nonhalogenated and chlorinated hydrocarbon compounds were detected in the soil vapor throughout the Propellant Burning Ground. In most cases, the strongest responses are centered around Waste Pits in the Contaminated Waste Area, although some compounds were detected over much of the Racetrack and Contaminated Waste Areas.

6.4.2.2 Geophysical Survey. GPR and magnetometer surveys were conducted at the 1949 Pit within the Propellant Burning Ground. TC and GPR surveys were conducted at Landfill 1. Surveys were conducted to aid in selection of sampling locations. The approach to these surveys is described in Subsection 6.2.2 and the detailed results are in Appendix C. At the 1949 Pit, the magnetometer survey identified a number of anomalies, the location of which delineated a north-south elongated rectangular area that corresponded well with aerial photographic interpretations. Subsequent traverses across the area with GPR supported the findings of the magnetometer survey. Areas included in the survey outside the interpreted boundary of the 1949 Pit generally did not contain anomalies. Results of the surveys were interpreted to indicate the presence of buried metallic wastes. Test pit excavations within the geophysical survey area have supported this interpretation, as substantial rebar, piping, construction debris, and a few empty powder drums were uncovered.

Generally, the TC survey at Landfill 1 indicated an elliptically shaped "high-conductivity" zone in the central portion of the study area; this could reflect the presence of metallic refuse and/or electrically conductive leachate within the landfill. A GPR survey conducted in this area indicated strong shallow reflections typical of landfill conditions. As shown in the figures in Appendix C, there is a striking similarity between the boundary mapped by TC contours and the shallow reflections identified by the GPR survey. The GPR and TC high response areas can therefore be interpreted as marking the boundary of the refuse fill. This area also corresponds to that shown to be filled in the historical aerial photography. The lack of a conductive zone downgradient (south) of the apparent boundary can be interpreted as meaning that either leachate high in dissolved solids is not migrating from the landfill, or that leachate infiltrates vertically and insufficient electrical contrast exists between leachate and groundwater to differentiate them through the approximately 100-foot-thick vadose zone.

6.4.2.3 Surface Soil. Surface soil samples were collected by ABB-ES at the Propellant Burning Ground. Surface soil and sediment samples from the Settling Ponds and Spoils Disposal Area were collected in four previous sampling programs by other contractors. A summary of the results of the four previous programs is presented in Subsection 6.4.2.3.2. No surface soil samples were collected by ABB-ES at Landfill 1. Background surface soil data is discussed in Section 2.0 and presented in Table 2-3.

6.4.2.3.1 Propellant Burning Ground

A summary of surface soil chemical data with detected results is presented in Tables 6-13 and 6-14. It should be noted that Table 6-13 lists only analytes with detectable concentrations in one or more of the samples from the Propellant Burning Ground. Appendix K lists all analytical results and Table 6-7 summarizes the analyses performed on surface soils. Figures 6-23 through 6-27 present selected chemical distribution in surface soils.

Summary and Interpretation of Surface Soil Results. Surface soil samples were collected from the Burning Pads, Burning Plates and Contaminated Waste Area of the Propellant Burning Ground. The primary chemicals detected in the surface soil samples include metals (i.e., CR, CU, PB, and ZN) at concentrations in excess of background and organic compounds (i.e., 24DNT and 26DNT).

In general, VOCs were detected at relatively low concentrations in surface soil at the Propellant Burning Ground (Table 6-13). The VOCs CCL4, TRCLE, and C6H6 were reportedly disposed of at the Propellant Burning Ground by dumping and/or open burning from plant start-up until January 1983. Of these VOCs, only C6H6 was detected in the surface soil samples. This distribution probably results from a combination of transport processes and backfilling of the Contaminated Waste Area and Waste Pits with clean soil. Volatilization to the atmosphere and downward migration in the soil column as a result of infiltrating precipitation are expected to be the predominant fates of VOCs disposed at the surface. Based on detected concentrations of VOCs and the processes discussed previously, it appears that surface soil at the Propellant Burning Ground does not currently represent a contamination source of VOCs.

The primary SVOCs detected in surface soils are 24DNT and 26DNT. Evidence from subsurface soil and groundwater analyses suggests the migration of DNTs to groundwater; however, the migration is very localized. Although DNTs were present in relatively high concentrations in surface soil at the Burning Pads (Table 6-13), it appears the dominant source for DNTs found in groundwater is subsurface soils (see Subsection 6.4.2.4.1).

The metals PB, CU, ZN, and HG detected at the Propellant Burning Ground are present in the highest concentrations in the Burning Pads area. This area was formerly used for open burning of waste propellant and by-products. Rocket paste contained as much as 1.2 percent (by weight) of both PB salicylate and PB ethylhexoate (Piercy, 1977). Open burning, reportedly on uncovered soil before installation of the concrete Burning Pads in 1983, appears to have resulted in contamination of surface soil in the area with the observed elevated concentrations of PB. AS detected in surface soils is not likely to be associated with propellant and by-product burning, but may be attributable to ash from AS-treated wood or treated packing material burned in the contaminated Waste Pits.

TCLP test results indicate that surface soil from some areas of the Propellant Burning Ground (especially the Burning Pads area) would be classified as RCRA hazardous waste according to TCLP criteria for PB (Table 6-14). Despite the lower concentrations of PB in subsurface soil samples, elevated concentrations in surface soil could represent a potential long-term source of leachable PB.

The following paragraphs present more detailed descriptions of chemical analysis results from the Propellant Burning Ground surface soil samples. A summary of surface soil contamination in the Settling Ponds and Spoils Disposal Area is presented in Subsection 6.4.2.3.2.

Organic Compounds. The distribution of selected VOCs, SVOCs, and DNTs in surface soil samples is shown in Figure 6-23. As indicated, C6H6 is the only VOC detected in surface soil samples with a concentration range from 0.199 to 2.64 μg/g. C6H6 was detected primarily around the Burning Pads. Several other VOCs (acetone [ACET], trichlorofluoromethane [CCL3F], methyl ethyl ketone [MEK]) sporadically detected at very low concentrations (<1 parts per billion [ppb]) are associated with laboratory method blank contamination (Appendix L).

SVOCs were detected in surface soil PBS-91-117, including acenaphthene (ANAPNE, 16.9 μg/g), acenaphthalene (ANAPYL, 1.04 μg/g), anthracene (ANTRC, 12.4 μg/g), benzo(a)anthracene (BAANTR, 8.9 μg/g), (BAPYR, 3.55 μg/g), benzo(b)fluoranthrene (BBFANT, 3.91 μg/g), benzo(g,h,i)perylene (BGHIPY, 2.57 μg/g), benzo(k)fluoranthrene (BKFANT, 3.36 μg/g), chrysene (CHRY, 8.28 μg/g), dibenzo(a,h)anthracene (DBAHA, 0.661 μg/g), (DEP, greater than 6.2 μg/g), fluoranthene (FANT, greater than 6.2 μg/g), fluorene (FLRENE, 18.4 μg/g), ideno(1,2,3-cd)pyrene (ICDPYR, 4.52 μg/g), phenanthrene (PHANTR, greater than 12 μg/g), and pyrene (PYR, greater than 6.2 μg/g). These SVOCs total to 115 μg/g.

24DNT, the most widely detected compound, was found in samples from the concrete Burning Pads and Contaminated Waste Area. 24DNT was detected in 16 samples (PBS-91-02, 05, 10, 13, 16, 25, 26, 27, 29, 32, 33, 34, 38, 41, 43, and 48) at concentrations ranging from 2.77 to 53.3 μg/g. 26DNT was detected in only two samples (PBS-91-10 and 26) at concentrations of 3.41 and 4.25 μg/g. These samples are either located in the immediate vicinity of the Burning Pads or in the vicinity of the Contaminated Waste Area. NNDPA analysis was performed on 16 samples. Of these, three resulted in detectable concentrations of NNDPA (PBS-91-10, 30, and 48) at concentrations of 1.22 to 30.8 μg/g. Two samples (PBS-91-10 and 30) were located immediately adjacent to the Burning Pads while PBS-91-48 was located in the Contaminated Waste Area.

Metals and Inorganic Compounds. Surface soil samples were analyzed for priority pollutant metals. Selected samples were also subjected to TCLP testing for CD, CR, PB, and HG. Table 6-13 lists the metals data for surface soil samples at the Propellant Burning Ground.

The principal inorganic contaminant of concern in surface soils at the Propellant Burning Ground appears to be PB. Background PB is on the order of 10 to 16 μg/g in surficial, on-post soils at BAAP and ranges upward to 30 μg/g in regional data. However, at the Propellant Burning Ground PB concentrations over 100 μg/g result in a consistent contaminant distribution as illustrated in Figure 6-24. Particularly high concentrations (>1000 μg/g) were detected near the Burning Pads west of the Racetrack and at selected locations near the Burning Plates east of the Racetrack. However, as Figure 6-24 indicates PB samples collected outside these areas have shown concentrations near background. PB concentrations well above background (120 μg/g to 2,200 μg/g) were also detected in the eight samples collected at the Contaminated Waste Area north of the Racetrack (Figure 6-25).

At the Burning Pads, PB concentrations in 17 samples were 1,000 μg/g or greater, and in 21 additional samples PB concentrations were in excess of 100 μg/g. The maximum PB concentration detected at the Burning Pads was 3,300 μg/g at PBS-91-37.

PB concentrations over 1,000 μg/g were detected in three samples, all collected in the southern portion of the Burning Plates area. PB concentrations in excess of 100 μg/g were detected in an additional six samples. The maximum PB concentration detected at the Burning Plates was 1,500 μg/g at PBS-91-118.

At the Contaminated Waste Area, three samples had PB concentrations over 1,000 μg/g while the remaining five samples had PB concentrations over 100 μg/g. The maximum PB concentration detected at the Contaminated Waste Area was 2,100 μg/g (PBS-91-43).

Other metals, including AS, AG, CD, CU, CR, HG, NI, antimony (SB), selenium (SE), and ZN were elevated above background concentrations (Table 2-3) at selected locations in the Propellant Burning Ground. Concentrations of metals were often elevated in a single sample. Samples with three or more metals detected above background concentrations include PBS-91-10 and 38 near the Burning Pads, PBS-91-41, 42 and 43 in the Contaminated Waste Area, and PBS-91-104 near the Burning Plates area. PBS-91-104 could reflect the composition of soils stockpiled in this area following excavation of ditches in the western Rocket Paste Area. The following provides a summary of the miscellaneous elevated metals detected in this area. Metals data is presented in Table 6-13; background metals data for surface soils is presented in Table 2-3.

AS concentrations above 16 μg/g are considered elevated above background concentrations. Three samples (PBS-41, 43, and 104) had AS concentrations of 24.7 to 64 μg/g.

Silver (AG) concentrations above 3 μg/g are considered elevated above background concentrations. One sample, PBS-91-38, had an AG concentration of 25.8 μg/g.

CD concentrations over 0.5 μg/g are considered elevated above background concentrations. Three samples (PBS-91-38, 41, and 42) had CD concentrations of 1.7 to 4.48 μg/g.

CU concentrations over 100 μg/g are considered elevated above background concentrations. Fourteen samples (PBS-91-04, 10, 13, 16, 17, 27, 32, 38, 41, 42, 43, 47, 48, and 104) had CU concentrations of 115 to 2,700 μg/g. An additional 16 samples had CU concentrations between 40 and 100 μg/g.

CR concentrations over 60 μg/g are considered elevated above background concentrations. Three samples (PBS 32, 41, and 104) had CR concentrations of 60.1 to 89.8 μg/g.

HG concentrations over 0.4 μg/g are considered elevated above background concentrations. Five samples (PBS-91-10, 23, 43, 48 and 104) had HG concentrations of 0.92 to 7.7 μg/g.

NI concentrations over 30 μg/g are considered elevated above background concentrations. Four NI concentrations between 30 and 38.1 were detected (PBS-91-10, 32, 37, and 47). However, these values are not considered adequately elevated to represent substantial contamination. One sample (PBS-91-10) had a NI concentration of 63.9 μg/g.

SB concentrations over 0.6 μg/g are considered elevated above background concentrations. One sample (PBS-91-38) had a SB concentration of 404 μg/g. SB was not detected in any of the other samples.

SE concentrations over 1 μg/g are considered elevated above background concentrations. Two samples (PBS-91-41 and 43) had SE concentrations of 1.11 and 2.03 μg/g.

ZN concentrations over 200 μg/g are considered elevated above background concentrations. Twenty-three samples (PBS-91-04, 06, 08, 10, 11, 13, 16, 17, 26, 27, 32, 33, 35 37, 38, 41, 42, 43, 45, 46, 47, 48, and 49) had concentrations between 202 and 5,200 μg/g. The overall distribution of ZN closely parallels that of PB with the highest concentrations occurring near the Burning Pads and Contaminated Waste Area.

In addition to chemical analyses for total metals in soil, TCLP tests for CD, CR, PB, and HG were performed on selected surface soil samples from the Burning Plates, Burning Pads, and Contaminated Waste Areas. A summary of the TCLP analytical results is presented in Table 6-14. Sample locations and distribution are shown in Figures 6-26 and 6-27. These tests were conducted to evaluate the leaching or migratory potential for the metals over time and to determine whether the surface soil would be considered a RCRA hazardous waste. No sample result from any of the three areas exceeded the TCLP regulatory level (RL) for CD, CR, or HG. No samples from the Burning Plates area exceeded the TCLP RL for PB (see Figure 6-26). Several samples (five of 17 samples tested) from the Burning Pads area exceeded the TCLP RL for PB; several of these samples exceeded the RL by one to two orders of magnitude, with a maximum PB leachate concentration of 100,000 μg/ℓ (PBS-91-10). Only two samples from the Contaminated Waste Area (PBS-91-48 and 49) exceeded the TCLP RL of 5,000 μg/ℓ for PB (see Figure 6-27).

6.4.2.3.2 Settling Ponds and Spoils Disposal Area

A summary of surface soil chemical data is presented in Table 6-15. Figure 6-28 presents a summary of selected SVOC and inorganic data for surface soils in the Settling Ponds and Spoils Disposal Areas. Individual sample locations are shown in Figure 6-10.

Summary and Interpretation of Surface Soil Results. Surface soils were collected from Final Creek and the Settling Ponds and Spoils Disposal Areas before 1989. Final Creek is a natural drainage swale modified to transmit wastewater from the WWTP to the Settling Ponds. The Settling Ponds were designed to serve as aeration and settling basins for the wastewater prior to its discharge to Gruber's Grove Bay in Lake Wisconsin.

ABB-ES has not conducted additional soil sampling at the Settling Pond and Spoils Disposal sites because the results and conclusions contained in the MEP are largely complete. The analysis presented herein is based on data from that document. In summary, it appears the Settling Ponds and Spoils Disposal Areas are impacted predominantly by the presence of PB above background concentrations. However, several other inorganic (ZN and SO4) and organic (di-n-octyl phthalate [DNOP], DPA, and NC) analytes were also detected, although not as ubiquitously as PB (Figure 6-28 and Table 6-15). In addition, it appears that concentrations of the various analytes decrease in the more eastern, downgradient (with respect to surface water flow) Settling Ponds and Spoils Disposal Sites. This likely reflects the deposition of greater quantities of sediments impacted by these analytes in the Settling Ponds closer to the Final Creek outfall. In addition, based on the analytes detected in groundwater, the analytes detected in the surface soils of Final Creek and the Settling Ponds and Spoils Disposal Areas have not been detected at concentrations above background in groundwater beneath the Settling Ponds, and are therefore not considered sources of groundwater contamination.

The following paragraphs present more detailed descriptions of chemical analyses results from the surface soil samples in Final Creek and the Settling Pond and Spoils Disposal Area. A summary of subsurface soil contamination at the Propellant Burning Ground is presented in Subsection 6.4.2.4.1

Final Creek. Chemical data from nine surface soil/sediment samples in Final Creek are summarized in the following paragraphs. Data is presented in

Table 6-15 (site ID's FC-1 through FC-8) and Table 6-16 (site ID SPB-91-01, depth equals 2.0 feet). The result of the chemical analysis from the nine surface soil/sediment samples revealed concentrations elevated above background for selected inorganic and organic parameters. The results of these analyses are summarized in Table 6-15. PB, NH3, and SO4 were detected at concentrations above background concentrations. PB was detected in one of the nine samples at a concentration of 40 μg/g which is above the 30 μg/g background sediment concentration. NH3 was detected at concentrations above the 320 μg/g maximum background concentration in only one of the eight samples submitted for NH3 analyses.

24DNT and 26DNT were detected in six of the nine samples, at maximum concentrations of 6 μg/g and 40 μg/g, respectively. 2-nitro-n-nitrosodiphenylamine (2NNDPA) was detected in three samples with a maximum concentration of 2 μg/g. DPA was detected in six of the nine samples, with a maximum concentration of 15 μg/g. The surface soil/sediment sample from SPB-91-01 (see Subsection 6.4.2.4) also contained low concentrations of a variety of SVOCs including ANAPYL, BAANTR, BBFANT, BKFANT, BGHIPY, CHRY, PHANTR, and PYR. The total concentration of these SVOCs was 3.658 μg/g and the highest concentration for a single compound was 0.723 μg/g. Results of EP toxicity leaching tests indicated concentrations did not exceed RCRA EP toxicity test criteria. All other surface soil/sediment results from Final Creek were either below background or risk levels (Tables 6-15 and 6-16).

Settling Pond 1. Surface soil/sediment samples from Pond 1 were fine-grained cohesive soils. Granular soils were encountered in the lower portion of some of the Shelby tube samples collected (Ayres Assoc., 1984). The sediments in Pond 1 were found to have a thickness of zero to 5 feet (Envirodyne Engineering, 1981). Eighteen surface soil/sediment samples were submitted for chemical analyses (Table 6-15). Results of the analyses are summarized in Table 6-15. The principal inorganic analytes detected above background concentrations are PB and SO4. PB was detected in four of 18 sediment samples at concentrations between 30 μg/g (maximum background sediment concentration) and 100 μg/g (Table 6-15). Three other samples had PB concentrations between 100 and 180 μg/g. SO4 was detected in eight of the 18 samples, with five of these samples having concentrations over 100 μg/g (Table 6-15). SO4 was not detected in background sediment samples collected at the Control Pond.

Organic analyses detected 24DNT and/or 26DNT in seven of 18 samples, with maximum concentrations of 172 μg/g and 40 μg/g, respectively. 2NNDPA was detected in only three of the 18 samples, with concentrations between 0.72 and 0.97 μg/g. DEP was detected in only one of the 18 samples, although its concentration was 460 μg/g. DPA was detected in six of the 18 samples with a concentration range of 0.24 to 10 μg/g. NC was detected in seven of the 18 samples, at a maximum concentration of 60,000 μg/g).

Results of EP toxicity tests on 14 of the samples from Pond 1 were below the RCRA EP toxicity test criteria.

Settling Pond 2. The sediments encountered in Pond 2 were typically described as silts with more granular sandy soils being encountered at depth. The results of chemical analyses on the four sediment/surface soil samples collected from Pond 2 are summarized in Table 6-15. The principal inorganic analytes detected above background concentrations in these samples from Pond 2 are PB, NIT, and SO4. PB was detected in three of the four samples with concentrations ranging from 95 to 250 μg/g. These are above the PB background concentration of 30 μg/g. NIT was also detected at concentrations ranging from 14 to 43 μg/g in three of the four sediment samples. Background NIT as measured at the Control Pond at BAAP was between 0.1 and 1.1 μg/g. SO4 was detected in one of the four samples at a concentration of 64 μg/g. SO4 was not detected in three background sediment samples collected at the Control Pond at BAAP.

Several VOCs were detected in the four samples from Pond 2 including 24DNT in one sample at a concentration of 7.6 μg/g, DEP in one sample at a concentration of 135 μg/g, DPA in one sample at a concentration of 1.5 μg and NC in two samples at concentrations of 260 and 280 μg/g (Table 6-15).

Results of EP toxicity tests on three of the samples from Pond 2 were below the RCRA EP toxic test criteria.

Settling Pond 3. Fine-grained silty soils grading to coarser sandy soils at depths to 5 feet were encountered in the samples from Pond 3. The analytical results from the 16 sediment/surface soil samples from Pond 3 are summarized in Table 6-15. The principal inorganic analytes exceeding background concentrations are PB and NH3. PB was detected in all 15 samples, although only two of the results exceeded the PB background level of 30 μg/g. Those three samples had PB concentrations of 30 and 34 μg/ℓ, and the reported values were close to background (Table 6-15). NH3 was also detected in all 15 samples analyzed for NH3, although only two of the samples, with concentrations of 463 μg/g and 520 μg/g, exceeded the background concentrations of up to 320 μg/g as measured at the Control Pond.

Several SVOCs were detected in the 16 sediment/surface soil samples submitted for laboratory analyses from Pond 3, although the number of detects and their concentrations were below those encountered in Pond 1. The SVOCs detected include: 24DNT in one sample at a concentration of 2.6 μg/g; 26DNT in one sample at a concentration of 1.5 μg/g; DEP in one sample at 44 μg/g; DPA in four samples at concentrations between 0.24 and 2.8 μg/g; and NC in two samples at concentrations of 50 and 190 μg/g.

Results of EP toxicity tests on 15 of the samples from Pond 3 did not exceed RCRA EP toxicity test criteria.

Settling Pond 4. The surficial soils encountered in Pond 4 were largely silts and clays with poorly graded sands in some areas. The analytical results from the 11 sediment/surficial soil samples collected in Pond 4 are summarized in Table 6-15. The principal inorganic analytes exceeding background concentrations are PB, NH3, and SO4. PB was detected in all 11 analytical samples, although concentrations greater than background (up to 30 μg/g) were detected in four samples, with a range between 100 μg/g and 300 μg/g. NH3 concentrations above background (up to 320 μg/g) and in six samples, with a range between 330 μg/g and 960 μg/g. Of the 11 samples analyzed for SO4, only three had detectable concentrations, ranging between 170 and 400 μg/g.

Organic analyses on the 11 samples from Pond 4 detected two organic compounds: DPA was detected in one sample at a concentration of 0.36 μg/g and NC was detected in two samples at concentrations of 50 and 1,038 μg/g (Table 6-15).

Results of EP toxicity tests conducted on 10 sediment/surface soil samples from Pond 4 did not exceed RCRA EP toxicity test criteria.

Spoil Disposal Site 1. Five surface soil samples were collected from Spoil Site 1 and the analytical results from these samples are summarized on Table 6-15. The principle inorganic compounds detected at Spoil Site 1 were PB, ZN, and SO4. PB was detected in all five samples at concentrations between 42 and 349 μg/g, which is above the regional background concentration of 30 μg/g. ZN was detected in four of five samples at concentrations between 128 and 212 μg/g above the site background concentration of 80 μg/g. SO4 was detected in three of the five samples at concentrations between 80 and 146 μg/g.

Organic analyses conducted on the five samples from Spoil Site 1 detected six different VOCs and SVOCs. However, the concentrations were all less than 34 μg/g. DNOP was detected in one of the five samples with a concentration of 8.6 μg/g. DPA was detected in four of the five samples with concentrations between 0.24 and 24 μg/g. NC was detected in all five samples at concentrations between 6,000 and 11,000 μg/g.

Spoil Disposal Site 2. Five surface soil samples were collected from Spoil Site 2 and the analytical results from these samples are summarized on Table 6-15. The principal inorganic analytes detected above background concentrations were again PB, ZN, and SO4. PB was detected in all five samples at concentrations between 239 and 373 μg/g, which is above the regional background concentration of 30 μg/g. ZN was also detected in all five samples at concentrations between 148 and 748 μg/g, above the site background concentration of 80 μg/g. Finally, SO4 was also detected in all five samples at concentrations between 80 and 130 μg/g.

Organic analyses conducted on the five samples from Spoil Site 2 detected five different VOCs. However, the concentrations were all less than 5.8 μg/g. DPA was detected in all five samples with concentrations between 0.24 and 3.2 μg/g. NC was also detected in all five samples at concentrations between 5,800 and 8,000 μg/g.

Spoil Disposal Site 3. Ten surface soil samples were collected from Spoil Site 3 and the analytical results from these samples are summarized on Table 6-15. The principal inorganic analytes detected above background concentrations were PB, ZN, and SO4. PB was detected in nine of 10 samples at concentrations between 34 and 67 μg/g which is above the regional background concentration of 30 μg/g but lower than the concentrations detected at Spoil Sites 1 and 2. ZN was detected in all 10 samples at concentrations between 84 and 251 μg/g, above the site background concentration of 80 μg/g. SO4 was detected in two samples at concentrations between 70 and 75 μg/g.

Organic analyses conducted on the 10 samples from Spoil Site 3 detected three different VOCs and SVOCs. However, the concentrations were all less than 4 μg/g. DNOP was detected in one of the 10 samples with a concentration of 0.42 μg/g. DPA was detected in four of the 10 samples with concentrations between 0.46 and 2.2 μg/g. NC was detected in all 10 samples at concentrations between 450 and 3,800 μg/g.

Spoil Disposal Site 4. Ten surface soil samples were collected from Spoil Site 4 and the analytical results from these samples are summarized on Table 6-15. The principal inorganic analytes detected above background concentrations were PB, ZN, and SO4. PB was detected in five of 10 samples at concentrations between 35 and 120 μg/g, which is above the regional background concentration of 30 μg/g, but is lower than the concentrations detected at Spoil Sites 1 and 2. PB was encountered less frequently at concentrations above the regional background concentration at Spoil Site 4 than at Spoil Site 3. ZN was detected in all 10 samples at concentrations between 89 and 204 μg/g, which is above the site background concentration of 80 μg/g. SO4 was detected in one sample at a concentration of 139 μg/g.

Organic analyses conducted on the 10 samples from Spoil Site 4 detected six different VOCs and SVOCs at concentrations less than 4.4 μg/g. DNOP was detected in three of the 10 samples, at concentrations ranging from 0.22 μg/g and 0.63 μg/g; DPA was detected in one of the 10 samples at a concentration of 1.1 μg/g. NC was detected in nine of the 10 samples at concentrations between 33 μg/g and 1,800 μg/g.

Spoil Disposal Site 5. Ten surface soil samples were collected from Spoil Site 5 and the analytical results from these samples are summarized on Table 6-15. The principal inorganic analytes detected above background concentrations were PB and ZN. PB was detected in five of 10 samples at concentrations between 35 μg/g and 102 μg/g, which is above the regional background concentration of 30 μg/g; but is lower than the concentrations detected at Spoil Sites 1 and 2. PB concentrations at Spoil Site 5 are similar to those encountered at Spoil Site 4. ZN was detected in nine of 10 samples at concentrations between 101 μg/g and 306 μg/g, which is above the site background concentration of 80 μg/g.

Organic analyses conducted on the 10 samples from Spoil Site 5 detected four different VOCs and SVOCs, with concentrations less than 6.5 μg/g. DNOP was detected in one of the 10 samples at a concentration of 0.2 μg/g. DPA was detected in three of the 10 samples with concentrations ran between 0.22 and 2.4 μg/g. NC was detected in one sample at a concentration of 11,000 μg/g; of the remaining nine samples, seven had detectable concentrations of NC, which ranged from 270 μg/g to 4,800 μg/g.

6.4.2.4 Subsurface Soil. Subsurface soil samples were collected for chemical analysis from soil borings and test pits in the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area. Background subsurface soil data is discussed in Section 2.0 and presented in Table 2-4. Discussions of the results are presented in the following Subsections.

6.4.2.4.1 Propellant Burning Ground

A summary of subsurface soil chemical data with detected results is presented in Tables 6-16 and 6-18. Table 6-16 only lists analytes with detectable concentrations in one or more of the subsurface soil samples from the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal areas. Appendix K contains analytical results, and Table 6-8 summarizes the analyses of subsurface soil samples. Figures 6-29 through 6-31 present selected chemical distribution in subsurface soils.

Summary and Interpretation of Subsurface Soil Results. Subsurface soil samples were collected for chemical analysis from test pits PBT-90-01 through PBT-91-08, soil borings PBB-90-01, -02, and PBB-91-01 through PBB-91-07. The eight test pits excavated within the area of the 1949 Pit revealed buried cast iron pipes, long steel supporting rods, metal sheeting, one crushed, empty powder drum (approximately 40-gallon capacity), and a small amount of oily contaminated soil. Soil borings PBB-90-01 and PBB-90-02 were drilled through the 1949 Pit. Soil borings PBB-91-01 through PBB-91-07 were drilled through or adjacent to Refuse Pits 1, 2, 3, Waste Pits 3, 2, 1, and the Old Burn Area, respectively. Locations of borings PBB-91-01 through PBB-91-07 at the Propellant Burning Ground were selected to coincide with areas of detected VOCs noted in the soil vapor survey results (see Appendix B).

The distribution of chemicals in the subsurface soil indicates the Waste Pits WP-1, WP-2, and WP-3 in the Contaminated Waste Area are potential sources of VOCs, SVOCs, NAMs, and DNTs detected in groundwater beneath the Propellant Burning Ground. Soil boring PBB-91-06 in WP-1 contains the highest concentrations of 24DNT, NNDPA, TRCLE, and C6H6 in a zone from 12 to 91 feet bgs.

Historical records indicate that WP-1, WP-2, and WP-3 were used to dispose of spent solvents and production wastes, possibly including deterrent. The two unfilled Waste Pits, WP-2 and WP-3 (PBB-91-04 and PBB-91-05), are approximately 12 to 15 feet deep. Borings PBB-91-04 and PBB-91-05 were placed at the edge of the unfilled waste pits because the center of the pits were inaccessible. As such, samples from these borings were collected from areas directly beneath these waste pits. Consequently, the results from these two borings likely underestimate maximum concentrations of VOCs and SVOCs in these pits. Concentrations of these chemicals are likely to be higher in the center of the pits, corresponding to areas of activity. All three pits likely represent potential sources of contamination of DNTs and VOCs in the groundwater.

In general, the majority of VOCs, SVOCs, and NAMs were detected at 12 feet or deeper. This is consistent with the depth of fill noted in PBB-91-06. The SVOCs most commonly reported, and at the highest concentrations, were 24DNT, 26DNT, and NNDPA. PBB-91-06 contains the highest concentration of 24DNT and 26DNT, in the same samples where high concentrations of VOCs were noted, thereby confirming that the interval from 12 to 91 feet bgs is a major zone of contamination. The highest DNT concentration was detected at 16 feet, where the soil sample contained 280,000 μg/g of 24DNT. PBB-91-04 has a contaminated zone between approximately 30 and 72 feet bgs. Two contaminated zones were associated with PBB-91-05, at WP-2: one from 24 to 32 feet bgs, and one from 69 to 73 feet bgs. Some of these apparent differences likely reflect the degree of lateral spreading of the contaminants outside the WP-2 and WP-3 pit boundaries.

The presence of DNTs at a depth of 91 feet bgs confirms the potential for these waste pits to be sources of groundwater contamination. The waste pits are a likely source of groundwater contamination due to the high concentrations detected. It should be noted that the concentrated contamination observed in PBB-91-06 extending to 91 feet bgs is approximately 10 to 15 feet above the water table. At 91 feet bgs, the concentrated contamination was observed in a very moist, fine to medium sandy zone. The sandy zone was underlain by coarser dry gravels containing much lower levels of contamination. It appears that contaminant viscosity as well as capillary attraction within the sandy zone may be inhibiting the downward gravity migration of concentrated contaminants into the coarser gravels.

This finding is significant as it suggests the concentrated contamination does not extend to the water table, thereby eliminating the potential for DNAPL (dense nonaqueous phase liquid) or LNAPL (light nonaqueous phase liquid) contamination at this site. This conclusion is generally supported by relatively low levels of contamination detected in groundwater samples from the numerous deep monitoring wells downgradient of the Propellant Burning Ground.

It appears the principal mechanism driving groundwater contamination is the passage of infiltrating precipitation through the concentrated contamination in the unsaturated zone.

VOCs are detected down to the same depths as the DNTs. However, volatilization of the VOCs, resulting in possible, lateral, migration coupled with partitioning into infiltration precipitation could contribute to a relatively large horizontal distribution of the VOCs. Zones of concentrated VOC and SVOC contamination similar to those identified at PBB-91-04, -05, and -06 were not detected in borings PBB-91-01, -02, -03, and -07. PBB-91-01, -02, and -03 were located in the Refuse Burning Pits along the southeast perimeter of the Racetrack Area. Lower concentrations of DNTs were detected in PBB-91-01 and PBB-91-02, although none were detected at depths deeper than 8 feet bgs in the soil beneath the Refuse Burning Pits. VOCs were detected in PBB-91-01 at 105 feet and in PBB-91-02 at 12 feet. However, the concentrations detected are much lower than those detected at the Waste Pits. PBB-91-07 was located in the Old Burn Area within the Contaminated Waste Area. Except for elevated concentrations of SO4, no analytes exceeded background concentrations, and no organic contaminants were identified in this boring. The Refuse Pits and Old Burn Area do not appear to represent a major source of potential contamination. Chemical data from PBB-91-07 also indicates that the maximum lateral spreading of VOCs and SVOCs in subsurface soils from the center of the Waste Pits is less than 125 feet, the distance from PBB-91-07 to WP-1.

Concentrations of PB and other metals above background levels are primarily limited to surface soils at the Propellant Burning Ground, with little evidence of vertical migration. PB, CU, and ZN concentrations detected in test pits and soil borings from the 1949 Pit area reflect this condition. Although concentrations of these metals are high in the upper 10 feet of the test pits and borings, they generally decrease with depth. This apparent lack of migration downward through the soil column is consistent with the expected environmental behavior of these metals under conditions likely to be encountered in natural soil and groundwater systems. In general, PB, CU, and HG are strongly bound by soil particles (particularly organic matter) and usually exhibit limited mobility except under very low or high pH conditions (i.e., pH less than 4 or greater than 9, or when they have formed mobile complexes). AS and ZN are generally considered moderately mobile compared to other metals, but may form stable bridged complexes with particle surfaces, and may be precipitated or coprecipitated with hydrous metal oxides of other species. High concentrations of PB in the surface soils at the Burning Pads and Plates are addressed in Subsection 6.4.3.3.1.

A more detailed and quantitative description of the chemical analysis results from subsurface soils in the Propellant Burning Ground is presented in the following paragraphs. A summary of subsurface soil contamination in Landfill 1 is presented in Subsection 6.4.2.4.2.

VOCs. Analytical results are summarized on Table 6-16. Boring PBB-91-06 (drilled through the center of Waste Pit 1) contained the highest levels of VOC contamination in the subsurface soils of the Propellant Burning Ground. Field observations recorded on the PBB-91-06 boring log indicate some samples were visibly contaminated (see Appendix D). In general, the highest concentrations of contaminants were detected in the upper 20 feet of the boring, although VOC contamination is evident to a depth of 71 feet bgs.

At PBB-91-06, C6H6 was detected in 13 of 14 samples (concentration range of 0.001 μg/g to 864 μg/g) (Figure 6-29). MEC6H5 and total combined xylenes (TXYLEN) detected in PBB-91-06 are believed to be associated with the detected C6H6. MEC6H5 and TXYLEN were detected in 11 of 14 samples with concentration ranges of 0.307 µg/g to 14.4 µg/g and 0.322 µg/g to 39.5 µg/g, respectively.

TRCLE was detected in 12 of 14 samples from PBB-91-06, with a range in concentration from 0.001 µg/g to 39.4 µg/g (see Figure 6-30). TRCLE concentrations drop off to less than 0.001 µg/g below 91 feet from ground surface.

Other VOCs detected in PBB-91-06 were 4-ethyl-2-methylhexane (4E2MHX), ethylbenzene (ETC6H5), methylisobutyl ketone (MIBK), and TCLEE. These compounds were each detected in three or fewer samples with a maximum concentration of 4.99 µg/g (Table 6-16).

Subsurface soil samples from other borings in the Contaminated Waste Area (PBB-91-04 and PBB-91-05) showed much lower levels of VOC contamination. Unlike boring PBB-91-06, these borings were drilled adjacent to Waste Pits 2 and 3, respectively. TRCLE was detected in PBB-91-04 (two of 15 samples, with a concentration range of 0.547 µg/g to 0.621 µg/g) and once in PBB-91-05 at a concentration of 0.253 µg/g (see Figure 6-30). Other VOCs detected in PBB-91-05 were 1,3-dimethylbenzene (13DMB) (0.434 µg/g and 0.849 µg/g), C6H6 (0.139 µg/g), ETC6H5 (0.204 µg/g), and xylenes (XYLEN, 0.992 µg/g). VOCs were not detected from samples in boring PBB-91-07, drilled in the Old Burn Area in the central portion of the Contaminated Waste Area.

Subsurface soil samples from borings drilled through Refuse Pits 1, 2, and 3, PBB-91-01, PBB-91-02, and PBB-91-03, respectively show very low concentrations of VOCs. Except for low concentrations in the 105-foot sample in PBB-91-01 and the 12-foot sample in PBB-91-02, VOCs are not considered to be contaminants of concern in subsurface soils beneath the Refuse Pits. The 12-foot sample from PBB-91-02 showed concentrations of 1,2-dichloroethylene (12DCE) and TRCLE greater than 10 µg/g, and concentrations of C6H6, MEC6H5, and TCLEE less than 9.1 µg/g.

The VOCs CH2CL2 and MEK were detected at low concentrations in many subsurface soil samples from borings in the Contaminated Waste Area and the Refuse Pits. CH2CL2 and MEK are laboratory artifacts observed in method blanks at low concentrations (see Appendix L), and historically have never been shown to be site contaminants at BAAP. Therefore, CH2CL2 and MEK are not considered to be site-related contaminants.

Analytical samples for the 1949 Pit Area were collected from two borings (PBB-90-01 and PBB-90-02) and eight test pits (PBT-90-01 through PBT-90-08). CCL4 was the only VOC detected, at 0.39 μg/g and 0.645 μg/g in PBT-90-07 at 3 feet bgs and PBT-90-08 at 5 feet bgs, respectively.

Although CCL4 is a major contaminant in groundwater beneath the Propellant Burning Ground, it was detected in only three subsurface soil samples, PBB-91-01 at 105 feet, PBT-90-07 at 3 feet, and PBT-90-08 at 5 feet, with a maximum concentration of 0.645 μg/g. CCL4 was not reported in PBB-91-06, where high levels of C6H6 and TRCLE were reported. In these samples, certified reporting limits for VOC target compounds were high because of the dilution required for C6H6. Although the chromatograms for these PBB-91-06 samples were reviewed in detail for the presence of CCL4, the possibility exists that CCL4 was present, but was not detected because of the higher certified reporting limits. A clearly defined source of CCL4 in the Contaminated Waste Area cannot be identified from these data.

SVOCs. A limited number of samples were selected from each boring and analyzed for SVOCs by GC/MS (Method LM25) and for NAMs by high performance liquid chromatography (HPLC) (Method LNO8); all samples were analyzed by HPLC for DNTs (Method LW23). The predominant SVOCs detected in the Propellant Burning Ground soils were 24DNT, 26DNT, and NNDPA, which were found in the borings at WP-1, -2, and -3, in the same zones where the primary VOCs were found (Figure 6-31). SVOC results are presented in Table 6-16. Samples were tested for 24DNT, 26DNT, and NNDPA by two methods (see Appendix L). In some samples, results of the HPLC DNT analyses agreed with results of the available GC/MS analyses. DNTs were not detected in samples from PBB-91-03, and -07 by either method. In some samples, DNTs were reported in one method and not the other. This is a result of different certified reporting limits for the two methods. This occurred in results from samples collected from PBB-91-04 at 72 feet, PBB-91-05 at 71 feet (26DNT), and PBB-91-06 at 12 feet (24DNT). The detection of DNTs by GC/MS verifies that these compounds were present in the subsurface soils. The lack of consistency between the two methods for some samples indicates that the distribution of DNTs is not uniform throughout the sample.

In general, the data indicate that the concentrations of 24DNT, 26DNT, and NNDPA are elevated in several subsurface soil samples from the Propellant Burning Ground. The higher concentrations of these compounds are found primarily in the Contaminated Waste Area, and are associated with Waste Pits 1, 2, and 3. At this time, it is believed that the DNTs observed in the soils beneath the Contaminated Waste Area act as a source material for migration into groundwater. Distribution of DNTs in groundwater is discussed in Subsection 6.4.2.5.2.

Particularly high concentrations of 24DNT and 26DNT are present in the subsurface soils beneath the Contaminated Waste Area, while lower concentrations were detected in selected sampling locations in the Refuse Pits and at the 1949 Pit.

Analytical samples were collected from four borings in the Contaminated Waste Area: PBB-91-04, PBB-91-05, PBB-91-06, and PBB-91-07. Boring PBB-91-06 (drilled through the center of Waste Pit 1) contained the highest concentrations of DNT and VOC contamination in the subsurface soils of the Propellant Burning Ground. In general, the highest concentrations of contaminants were detected in the upper 20 feet of the boring, although contamination by explosives is evident to a depth of at least 91 feet bgs.

DNTs were detected in 11 of 13 samples from PBB-91-06 (see Figure 6-31). 24DNT concentrations ranged from 57.9 μg/g to 280,000 μg/g, and 26DNT concentrations ranged from 5.01 μg/g to 1,000 μg/g. NNDPA was detected in two samples (12 and 91 feet bgs) with a maximum concentration of 14.1 μg/g.

Other SVOCs detected in PBB-91-06 include 2-methylnaphthalene (2MNAP), bis-(2-ethylhexyl)phthalate (B2EHP), DNBP, NAP, and n-butyl ether (NBUETH).

Subsurface soil samples from other borings in the Contaminated Waste Area (PBB-91-04 and PBB-91-05) showed much lower concentrations of DNTs and NAMs (see Figure 6-31). These borings were drilled adjacent to Waste Pits 2 and 3. 24DNT was detected in PBB-91-04 (four of 14 samples, with a concentration range of 66.5 μg/g to 1,500 μg/g) and in PBB-91-05 (five of 12 samples, with a concentration range of 5.52 μg/g to 3,500 μg/g). 26DNT was detected once in PBB-91-04 at a concentration of 10.5 μg/g, and once in PBB-

91-05 at a concentration of 1.48 μg/g. NNDPA was detected once in PBB-91-04 (230 μg/g) and twice in PBB-91-05 (maximum of 0.769 μg/g). PBB-91-07, drilled in the Old Burn Area in the central portion of the Contaminated Waste Area, showed no detects of SVOCs.

Subsurface soil samples from borings drilled through Refuse Pits 1, 2, and 3 (PBB-91-01, PBB-91-02, and PBB-91-03, respectively) show very low levels of DNTs. 24DNT was detected in the 8-foot sample in PBB-91-01 at a concentration of 165 μg/g, and in the 4-foot sample in PBB-91-02 at a concentration of 58.9 μg/g. 26DNT was detected in the 8-foot sample in PBB-91-01 at a concentration of 5.96 μg/g.

Analytical samples for the 1949 Pit Area were collected from two borings (PBB-90-01 and PBB-90-02) and eight test pits (PBT-90-01 through PBT-90-08). 24DNT was detected in the subsurface soil samples from the 1949 Pit Area at concentrations of 12.282 μg/g and 6.127 μg/g in PBT-90-05 and PBT-90-06, respectively.

Metals and Inorganics. All subsurface soil samples collected from borings in the Propellant Burning Ground were analyzed for priority pollutant metals. In addition, some samples were extracted using the TCLP method and the extract was analyzed for CD, CR, HG, and PB. TCLP analyses indicate that none of the samples would be considered hazardous.

PBB-91-01, PBB-91-02, and PBB-91-03 are located south of the Racetrack in the Refuse Pits (RP-1, RP-2, and RP-3). In most cases, metals in subsurface soil samples from these borings were detected in ranges typical of background levels (see Table 6-16); however, concentrations of some metals were higher than background concentrations in certain samples from PBB-91-01 and PBB-91-02 (Tables 2-3 and 6-16). Analyses of subsurface soil samples from borings at and near the Waste Pits of the Contaminated Waste Area indicate metals were generally within background ranges, except in the shallow and fill soils (approximately 1 to 12 feet). Notably AS, CR, CU, PB, and ZN were detected at concentrations more than 10 times the estimated background range in RP-1 and RP-2. In these borings, concentrations above background occur in the same zone as the noted contamination by organic compounds.

Metals concentrations in all borings from the Contaminated Waste Area are near background levels, with the exception of several slightly elevated concentrations of SE and PB in the upper section of boring PBB-91-06 (Table 6-16).

In the 1949 Pit Area, CU, PB, and ZN were substantially elevated above background concentrations in nearly all the test pits, PBT-90-01 through PBT-90-08, but were within background levels in borings PBB-90-01 and PBB-90-02. Of the 16 test pit samples analyzed for CU, PB, and ZN: seven have concentrations of CU greater than 100 μg/g (maximum of 5,945.5 μg/g), 11 have concentrations of PB greater than 100 μg/g (maximum of 5,371.5 μg/g), and 11 have concentrations of ZN greater than 200 μg/g (maximum of 2,984.4 μg/g).

At the Propellant Burning Ground, 26 subsurface soil samples were collected at various depths from seven soil borings and analyzed by TCLP methods for CD, CR, HG, and PB. Table 6-17 lists the samples analyzed and summarizes the results. The tests were conducted to evaluate the leaching or migratory potential for CD, CR, HG, and PB in subsurface soil at the seven boring locations in the Propellant Burning Ground to determine if the soil at these locations would be characterized as a hazardous waste because of its toxicity characteristics. At borings PBB-91-01, 02, 03, 05 and 07, CD, CR, HG, and PB were not detected above the certified reporting limit in any of the samples analyzed using TCLP. At PBB-91-04, only PB was detected at 122 μg/ℓ (18 feet bgs) and 95 μg/ℓ (72 feet bgs). At PBB-91-06, CR was detected at 9.5 μg/ℓ (12 feet bgs) and 10.1 μg/ℓ (14 feet bgs), PB was detected at 1,460 μg/ℓ (12 feet bgs) and 167 μg/ℓ (14 feet bgs), and CR was detected at 22.8 μg/ℓ (41 feet bgs). None of the concentrations of the metals detected exceeded the TCLP regulatory levels.

Most subsurface soil samples were analyzed for the anions SO4 and NIT; the results are in Appendix K. SO4 concentrations ranged from below detection level to 280 μg/g. NIT concentrations ranged from below detection level to 35 μg/g. Background concentrations of NIT in subsurface soils (as reported in Section 2.0) range from less than 1.0 μg/g to 4.07 μg/g. SO4 concentrations in these same background soil samples were less than 5 μg/g.

6.4.2.4.2 Landfill 1

A summary of subsurface soil chemical data with detected results is presented in Table 6-16. It should be noted that Table 6-16 only lists analytes with detectable concentrations in one or more of the subsurface soil samples from the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal areas. Appendix K contains complete analytical results, and Table 6-8 summarizes the analyses performed on subsurface soil samples.

<u>Summary and Interpretation of Subsurface Soil Results</u>. Ten subsurface soil samples were collected for chemical analysis from LOB-90-01 and LOB-90-02. LOB-90-01 was drilled near the center of Landfill 1, and encountered fill material from ground surface to a depth of 15 feet. LOB-90-02 encountered only 1 foot of fill material over native soil at the periphery of Landfill 1. Historical records indicate that Landfill 1 was used to dispose of structural timbers, asphalt shingles, cardboard, office refuse, and other unknown material. In addition, the MEP reported that open burning of propellants, extraction wastes, C6H6, and black powder was conducted at the site. No VOCs or SVOCs were detected in the borings. However, concentrations of metals above background were detected in the fill and ash of the upper 10 feet of the borings. These elevated concentrations of metals decrease to background concentrations with increasing depth below the fill material. The exception to this trend is seen in the 20- and 25-foot samples from LOB-90-01, where elevated concentrations of CU were detected. This apparent lack of migration is consistent with the expected environmental behavior of these metals under conditions likely to be encountered in soil and groundwater systems. In general, metals such as CU and PB are strongly bound by soil particles (particularly organic matter) and usually exhibit limited mobility except under very low or high pH conditions. Based on available data, Landfill 1 does not appear to represent a major source of potential contamination to groundwater beneath the site.

A more detailed and quantitative description of the chemical analysis results from subsurface soils from Landfill 1 is presented in the following paragraphs. A summary of subsurface soil contamination in the Settling Ponds and Spoils Disposal Areas is presented in Subsection 6.4.2.4.3.

CU, PB, and ZN concentrations (837.106 μg/g, 1,343.194 μg/g, and 1,695.162 μg/g, respectively) were higher in the 10-foot LOB-90-01 sample than in any other sample. CU was detected in all samples from LOB-90-01, ranging from a low of 4.465 μg/g (86 feet bgs) to 837.106 μg/g (10 feet bgs). CU was detected at 103.108 μg/g in the zero-foot sample of LOB-90-02. PB was detected in three of nine samples in LOB-90-01, with a concentration range from 62.851 μg/g to 1,695.162 μg/g. PB was detected at a concentration of 73.211 μg/g in the zero-foot sample from LOB-90-02. ZN was detected in all samples from LOB-90-01, ranging from a low of 3.110 μg/g (140 feet) to 1,695.162 μg/g (10 feet bgs). ZN was detected at 108.713 μg/g in the zero-foot sample of LOB-90-02. Other metals detected above background concentrations in the 10-foot sample of LOB-90-01 include AS (36.88 μg/g), CD (2.689 μg/g), CR (114.412 μg/g), and NI (95.355 μg/g).

6.4.2.4.3 Settling Ponds and Spoils Disposal Area

A summary of subsurface soil chemical data with detected analytical results is presented in Tables 6-16 and 6-18. It should be noted that Table 6-16 only lists analytes with detectable concentrations in one or more of the subsurface soil samples from the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal areas; Appendix K contains complete analytical results for SPB-91-01 samples; Table 6-8 summarizes the analyses performed on SPB-91-01 samples.

Summary and Interpretation of Subsurface Soil Results. Boring SPB-91-01 was drilled under the direction of ABB-ES in the Settling Ponds and Spoils Disposal Area at Final Creek south of the WWTP (see Figure 6-10). During periods of installation operation, Final Creek conveyed up to 60 million gallons per day of process wastewater from the general purpose and industrial sewer to the Settling Ponds. SPB-91-01 was drilled to assess the potential impact on the soil in and below Final Creek as a result of wastewater transport to the Settling Ponds.

Subsurface soil sampling at the Settling Ponds and Spoils Disposal Area was performed by Envirodyne Engineers, Inc. (1981). Seven borings, S1201 through S1207, were drilled in 1980 to assess potential subsurface contamination in Settling Ponds 1 through 4 (see Figure 6-10). Samples from these borings were composited over depths of zero to 15 feet and to 30 feet bgs. As the samples are composites no attempt is made to discuss their concentrations with depth.

In general, concentrations of contaminants decrease downstream from Final Creek to Settling Pond 4, and also with increasing depth from ground surface. None of the analytes detected in subsurface soils are found in groundwater at concentrations above background beneath the Settling Ponds and Spoils

Disposal Area; therefore, subsurface soils in this area are not considered a source for groundwater contamination (i.e., CCL4, CHCL3, TRCLE) detected in groundwater beneath Final Creek.

The SVOCs detected in the Final Creek, boring SPB-91-01, 2-foot sample are low in concentration and have not typically been detected in soil samples at BAAP. HG, detected in the 2-foot sample of SPB-91-01, is known to have been used in various agricultural fungicides and pesticides. However, no documentation of the use of these compounds at BAAP has been identified. Thallium (TL) was also detected in samples from SPB-91-01. However, elevated concentrations of TL were not commonly detected in other soil samples at BAAP.

The subsurface soils collected from the Settling Ponds were analyzed for a limited set of analytes (see Table 6-18). 24DNT, DNBP, DEP, NC, and PB detected in the samples are attributable to processes undertaken during production periods at BAAP. Verified migration of these contaminants in subsurface soils at the Settling Ponds appears limited. However, definition of the depth of these contaminants is somewhat difficult to interpret because of the composite sampling intervals.

A more detailed and quantitative description of the chemical analysis results from subsurface soils in Final Creek and the Settling Ponds and Spoils Disposal Area is presented in the following sections.

Final Creek. The primary contaminants detected in the six analytical samples from SPB-91-01 were SVOCs, HG, and TL in the 2-foot sample (see Table 6-16). SVOCs in the sample totaled 3.658 μg/g and include ANAPYL, BAANTR, BBFANT, BGHIPY, BKFANT, CHRY, PHANTR, and PYR. The highest concentration of the SVOCs was 0.723 μg/g of BBFANT. B2EHP was also detected in the 2-foot sample at a concentration of 1.02 μg/g. Very low concentrations of C6H6 and MEK were reported in the 67-foot sample. MEK was detected in the laboratory method blank, and C6H6 is also believed to be a laboratory contaminant (Appendix L).

The metals TL and HG were detected in SPB-91-01 at concentrations exceeding background. TL was detected from ground surface to a depth of 22 feet bgs, with a concentration range from 0.156 μg/g to 17.0 μg/g. The reported regional data range for TL in surface soils is 0.02 μg/g to 2.8 μg/g, and the mean concentration of TL in background subsurface soils is less than 2.7 μg/g (Table 2-4). HG was detected in the 2-foot sample at a concentration of 0.505 μg/g. All other metals and anions in samples collected from boring SPB-91-01 were within background ranges for surface and subsurface soils.

Settling Pond 1. The primary contaminants detected in borings S1201 through S1204 were 24DNT, DEP, NC, and PB (Table 6-18). 24DNT was detected at a maximum concentration of 681 μg/g (boring S1202). DEP was detected at a maximum concentration of 1,340 μg/g (boring S1202). A maximum concentration of 59,900 μg/g of NC was detected in boring S1201. PB concentrations were slightly elevated above background, with a maximum concentration of 180 μg/g (S1204). In addition, tin (SN) and SO4 were detected at concentrations above background concentrations.

Settling Ponds 2, 3, and 4. Borings S1205, S1206, and S1207 were drilled in Settling Ponds 2, 3, and 4, respectively. In general, concentrations of the primary contaminants decrease downstream from Ponds 2 to 4, and Gruber's Grove Bay. The maximum concentrations of 24DNT, DEP, and PB were detected in Pond 2 at levels of 7.57 μg/g, 135 μg/g, and 165 μg/g, respectively. SO4 and SN were detected at concentrations slightly above background. NC, which had a maximum concentration of 1,030 μg/g, was the only primary contaminant detected at a higher concentration in the downstream (S1207) sample.

6.4.2.5 Groundwater. Groundwater chemistry is presented as one section for the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Areas. The primary contaminants of concern in groundwater beneath the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area are 111TCE, 26DNT, CCL4, CHCL3, and TRCLE. For a contaminant to be considered representative of actual site conditions, it must be detected in at least two rounds of sampling at a given well. Because of the volume of data, the distribution and extent of each class of chemicals is discussed, followed by an interpretation of their presence and migration in the groundwater. Table 6-19 summarizes the detected chemical groundwater data. This table only lists contaminants with detectable concentrations in one or more of the monitoring wells sampled. Appendix K lists complete analytical results and Table 6-9 summarizes the analyses performed on groundwater samples. Two limited sampling rounds were conducted by ABB-ES during September 1990 and October 1990 (Round I and Round II, respectively) and are presented in Table 6-19. These two limited rounds of sampling were for select VOCs, and results agree well with those of Round One (November/December 1991) and Round Two (April/May 1992). Therefore, these data are not discussed separately in the following Subsection 6.4.2.5.1. Distribution and concentrations of selected groundwater contaminants are presented in Figures 6-32 through 6-39. Background groundwater data is discussed in Section 2.0 and presented in Table 2-6.

6.4.2.5.1 Volatile Organic Compounds

Analytical methods used for VOC analyses in groundwater samples by both laboratories (i.e., Datachem and A.D. Little, Inc.) were GC/MS analyses; however, certified reporting limits for each analyte differ between laboratories (see Appendix L).

To eliminate confusion caused by differences in certified reporting limits, VOCs reported at concentrations below 5 $\mu g/\ell$ are referred to as trace levels even if, because of lower certified reporting limits, a more exact concentration is known. This 5 $\mu g/\ell$ limit is equal to or below most federal and WDNR groundwater quality standards (see Table 3-3). Despite variations in sampling times and analytical methods (DataChem and A.D. Little), the data consistently define a plume of VOCs extending from the northern edge of the Propellant Burning Ground to south of the installation boundary. This plume is relatively shallow near the Propellant Burning Ground and is observed to extend deeper in the sand and gravel groundwater system south of the Propellant Burning Ground.

<u>Summary and Interpretation of VOC Results</u>. Groundwater beneath the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area has been shown to be contaminated with VOCs (i.e., CCL4, TRCLE, CHCL3, and 111TCE). The VOC contamination appears to be migrating southward from the Propellant Burning Ground Area and deeper into the sand and gravel aquifer. Data from off-post wells south of BAAP confirm that VOCs have migrated off installation (see Section 11.0). The following paragraphs provide interpretations of (1) the historical use and source of VOCs at BAAP, and (2) the behavior of the VOC groundwater contamination in the Propellant Burning Ground, Landfill 1, and the Settling Pond and Spoils Disposal Area.

Historically, CCL4 had been used at BAAP since the 1940s, and probably was the predominant degreaser and solvent used before the 1960s. After 1970, the use of CCL4 was curtailed by the federal government. TRCLE replaced CCL4 as the primary solvent. 111TCE, found in groundwater, is believed to have been used as a degreaser and solvent at BAAP, or existed as an impurity in other solvents such as TRCLE. The source of CHCL3 found in groundwater is unknown.

No significant or definitive source of CCL4 was found in the surface or subsurface soils at the Propellant Burning Ground and Landfill 1. CCL4 was reportedly burned with propellants on the ground surface at the Propellant Burning Ground from 1942-45, 1951-56, and 1966-71 (USAEHA, 1985). Inspection of the passive soil gas data for CCL4 (Appendix B) indicates widespread detections of CCL4 vapor in the Racetrack Area, and in small areas in, and north of, the Contaminated Waste Area. The only detects of CCL4 in laboratory analytical data from soils were in the 1949 Pit Area in soil boring PBB-90-01, and test pits PBT-90-07 and PBT-90-08 (see Table 6-16). Detected levels were less than 1 $\mu g/g$.

Figure 6-2 reveals the chronological evolution of the Propellant Burning Ground. Correlating this physical development with the history of VOC use at BAAP indicates CCL4 was probably not disposed of in the waste pits of the Contaminated Waste Area. This is confirmed by subsurface soil data from borings PBB-91-04, 05, and 06, which did not indicate any detection of CCL4. The location of the source of CCL4 detected in groundwater is unknown. Based on observed evolution of the Propellant Burning Ground from aerial photographs, and the substantial width of the CCL4 groundwater plume (2,000 feet), the source might be spread out over the entire area. However, it is also possible that gas-phase transport of CCL4 in the unsaturated zone and transport to the water table via partitioning to infiltrating precipitation, is responsible for the large extent of the plume in the Propellant Burning Ground Area.

Within the groundwater samples CCL4 concentrations of approximately 100 $\mu g/\ell$ are detected in two zones: one just south of the Racetrack Area, and the other at the southern base boundary. Between these two zones, concentrations of CCL4 decrease to less than 40 $\mu g/\ell$. Several possible explanations for these conditions are: (1) the heterogeneity of the soils and screened intervals of monitoring wells are responsible for the observed CCL4 distribution, (2) disposal of CCL4 during distinct time periods (i.e., World War II, the Korean War, and the Vietnam Conflict), and/or (3) the two areas of elevated CCL4 concentrations are evidence of "pulses" of CCL4 from a source in the soils in the vicinity of the Propellant Burning Ground (e.g., natural leaching by infiltration is a cyclical process).

Relatively low concentrations of CCL4, TRCLE, and CHCL3 were observed at the water table at Landfill 1. However, the concentrations were similar upgradient and immediately downgradient of Landfill 1. No source of VOCs was found in subsurface soils from borings LOB-90-01 and 02. One possible explanation for detection of VOCs in groundwater beneath Landfill 1 is a combination of subsurface lateral as well as vertical dispersion and/or vapor-phase transport through the unsaturated zone from suspected source areas to the west at the Contaminated Waste Area. Decreasing concentrations of VOCs to the north of Landfill 1 in wells LOM-89-01, LOM-91-01, and 02 appear to indicate that there is no source area upgradient of Landfill 1.

The most likely source area for TRCLE detected in groundwater is the Contaminated Waste Area in the Propellant Burning Ground. TRCLE was detected in subsurface soils beneath and adjacent to Waste Pits 1, 2, and 3 at concentrations in excess of 39 μg/g. The Waste Pits appeared between 1968 and 1974 (see Figure 6-2), which correlates well with the reported historical use of TRCLE at BAAP. The USAEHA (1985) reported that TRCLE was burned with lumber in the three Waste Pits. Passive soil vapor survey results confirm the presence of TRCLE in subsurface soils beneath the Waste Pits of the Contaminated Waste Area. The relatively low concentrations and less consistent detection of TRCLE in groundwater at the southern base boundary support the fact that TRCLE was used (and disposed of) at BAAP more recently than CCL4.

The highest concentrations of TRCLE detected in groundwater are immediately south of the Contaminated Waste Area in well PBN-82-02B. The TRCLE plume is similar in horizontal extent to the CCL4 plume, with the exception of being half the width of the CCL4 plume at the base boundary. TRCLE was detected upgradient (well PBM-89-09) and cross-gradient (wells PBM-82-01 and LON-89-03) from the suspected sources in the Contaminated Waste Area. This may be the result of a combination of subsurface lateral as well as vertical dispersion and/or vapor-phase transport through the unsaturated zone from the subsurface soils beneath the Contaminated Waste Area.

CHCL3 was detected in two rounds of sampling in 55 of 91 wells in the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area. Concentrations of CHCL3 detected in groundwater were generally less than 10 μg/ℓ. The distribution of CHCL3 is nearly identical to that of CCL4. One potential source of CHCL3 is the anaerobic degradation of CCL4 by hydrogenolysis (Vogel, et al., 1987). This potential source of CHCL3 is supported by the observed distribution of CHCL3 in groundwater, which is nearly identical to that of CCL4. Another potential source for CHCL3 is the subsurface soils in the Contaminated Waste Area. Although no CHCL3 was detected in soils by ABB-ES, the MEP reports CHCL3 in subsurface soils at the Contaminated Waste Area ranging from 1 to 2 μg/g. Because of its high vapor pressure and poor soil affinity, CHCL3 detected in subsurface soils in the mid-1980s (and reported in the MEP) could have evaporated and/or partitioned into infiltrating precipitation. CHCL3 might also have been an impurity in solvents (e.g., CCL4) used at BAAP.

111TCE is commonly used as a degreasing agent, and was probably used at BAAP. Groundwater data from the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area indicate that the source for 111TCE is in the vicinity of the Propellant Burning Ground. 111TCE was also found in groundwater at the Deterrent Burning Ground (see Section 7.0). 111TCE was detected infrequently in subsurface soil samples from the Contaminated Waste Area, and at concentrations less than 0.005 μg/g. These concentrations and frequency of detection do not indicate a significant current source of 111TCE in subsurface soils, suggesting limited use/disposal of 111TCE at the site. One hypothesis is that the 111TCE has evaporated and/or been leached from the subsurface soils. Another possibility is that an unidentified source of 111TCE exists in the vicinity of the Propellant Burning Ground.

Based upon observed concentrations of C6H6 in subsurface soils of the Contaminated Waste Area, one would expect to find C6H6 in groundwater beneath the Propellant Burning Ground. However, C6H6 was detected only once, in well PBN-82-04C at a concentration of 1.76 μg/ℓ.

A more detailed and quantitative description of the distribution of VOCs at the Propellant Burning Ground, Landfill 1 and Settling Ponds and Spoils Disposal Area is presented in the following section. A summary of SVOC results is presented in Subsection 6.4.2.5.2.

Distribution of VOCs. Data presented in this RI Report was gathered during sampling Round One (November and December 1991) and Round Two (April and May 1992), and are in general agreement with the distribution presented in the MEP (Tsai et al., 1988). Data from wells installed by ABB-ES indicate both a larger and deeper contaminant plume than described previously in the MEP. This is a result of further characterization of the contaminant distribution. The contaminant plume extends farther south of the Propellant Burning Ground and into the deeper portions of the sand and gravel aquifer in the southern region near the Settling Ponds. Additional data from the analysis of samples collected from monitoring wells and private wells south of the installation boundary shows that the plume extends south beyond the BAAP facility boundary (see Section 11.0).

Results in Rounds One and Two indicate that several VOCs are present in groundwater beneath the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area. The VOCs observed most frequently and at the highest concentrations were CCL4, TRCLE, CHCL3, and 111TCE. Concentrations for all detected analytes are shown in Table 6-19 for the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area, and summarized in the following paragraphs. Figure 6-32 presents the distribution of CCL4, TRCLE, CHCL3, and 111TCE detected in Rounds One and Two of groundwater sampling. In addition to these VOCs, other chemicals including impurities and degradation products of TRCLE, CCL4, and fuels were identified: 1,1-dichloroethylene (11DCE), 1,1-dichloroethane (11DCLE), 13DMB, C6H6, and MEC6H5 were detected in wells located near the current and former burning areas. Most of these VOCs were reported in the first sampling round at trace levels (less than 5 $\mu g/\ell$). No consistent spatial or temporal pattern of detection was observed. Although 11DCLE, 13DMB, C6H6, and MEC6H5 are likely to be related to the established VOC plume, they were not used to define the plume.

The VOCs CCL4, TRCLE, CHCL3, and 111TCE are found in most wells in the Propellant Burning Ground. CCL4 was detected in 61 of 92 wells with a maximum concentration of 108 $\mu g/\ell$ (PBN-85-02A, Round Two);

concentrations in all 61 wells exceeded the WPAL of 0.5 μg/ℓ, and the WES of 5 μg/ℓ was exceeded in 40 wells. TRCLE was detected in 65 of 92 wells with a maximum concentration of 117 μg/ℓ (PBN-82-02B Round One); concentrations in all 65 wells exceeded the WPAL of 0.18 μg/ℓ, and the WES of 5 μg/ℓ was exceeded in 42 wells. CHCL3 was detected in 70 of 92 wells with a maximum concentration of 83.5 μg/ℓ (PBN-85-01A Round One); concentrations in 67 wells exceeded the WPAL of 0.6 μg/ℓ, and the WES of 6 μg/ℓ was exceeded in seven wells. 111TCE was detected in 17 of 92 wells with a maximum concentration of 59.3 μg/ℓ (PBN-8-03A Round One); concentrations in four of the wells exceeded the WPAL of 40 μg/ℓ.

Based on a review of the quality control data, the detection of ACET, CH2CL2, and MEK are the result of laboratory contamination. These analytes were detected in method and/or trip blanks (see Appendix L).

The horizontal distribution of CCL4 and TRCLE is illustrated in Figures 6-33 and 6-34, respectively. Figure 6-35 shows the orientation of the contaminant plume cross sections for CCL4 and TRCLE, which are illustrated in Figures 6-36 and 6-37, respectively. These chemicals have been chosen for visual representation because they best represent the VOC plume. The concentrations of TRCLE are highest at the water table in the vicinity of the Contaminated Waste and Racetrack Areas. The concentrations of CCL4 are highest just south of the Racetrack Area and in the groundwater samples collected from wells that have screens located approximately 40 to 100 feet below the water table along the southern boundary. 111TCE was detected in wells in the central sections of the site, immediately downgradient of the racetrack in well PBN-85-02A, and as far south as PBN-89-04B and C. The following paragraphs discuss each of the VOC plumes on an analyte-specific basis.

The CCL4 plume extends longitudinally from just north of the Propellant Burning Ground to south of the base boundary with an average width of 3,000 feet (Figure 6-33). The highest concentrations of CCL4 are detected south to southeast of the Racetrack Area in water table wells, and at the base boundary in the deeper "C" and "D" wells (see Figure 6-32). Concentrations of CCL4 in the vicinity of the Propellant Burning Ground are generally lower than those reported in the September 1986 sampling event from the MEP. However, the distribution is quite similar to that indicated in the MEP. PBN-85-03A, PBM-85-02, PBN-85-01A, PBM-85-03, and PBN-85-02A form a line (fence) of wells extending west to east (perpendicular to the direction of groundwater flow), south of the Propellant Burning Ground. CCL4 was detected in almost all wells during Rounds One and Two. However, wells on the eastern side of this well fence have higher VOC concentrations than the wells on the western side.

In addition to the wells installed near the Propellant Burning Ground, wells were installed to assess the impact of Landfill 1. Wells LOM-89-01, LON-89-02A and B, LON-89-03A and B, LOM-91-01, and LOM-91-02 were installed around Landfill 1. CCL4 was detected in these wells with the exception of LOM-91-02 (see Figure 6-32).

At the base boundary, CCL4 is distributed from well S1133 located in the southwest corner of the base to the east at well S1103 located south of Settling Pond 1. It should be noted that this eastern boundary of the plume is not as precisely defined as it is on the western boundary of the plume. At the base boundary the concentrations of CCL4 are higher in the deeper "C" and "D" wells than the water table wells. The 1989 and 1991 well nests installed south of the Settling Ponds and Spoils Disposal Area were initially installed to define the extent of the NIT plume suspected to be emanating from this area. However, VOCs characteristic of the Propellant Burning Ground plume (i.e., CCL4 and TRCLE) were detected in wells S1133, SPN-89-01C, SPN-89-02 B and C, SPN-91-02D, SPN-89-03 B and C, SPN-91-03D, SPN-89-04 B and C, and S1103 in both Round One and Round Two. These data confirm that CCL4 contamination exists further south than was previously described in the MEP.

Figure 6-36 illustrates the estimated vertical extent of the CCL4 from the Propellant Burning Ground in the north to the base boundary in the south. These data support the interpretation that the VOC plume is moving deeper into the sand and gravel aquifer as it moves southward.

TRCLE, CHCL3, and 111TCE plumes are also present in the groundwater beneath the Propellant Burning Ground. TRCLE distribution in groundwater is very similar to that of CCL4 (see Figures 6-33 and 6-34). The major difference is the narrower width of the TRCLE plume, particularly near the base boundary where it is approximately one-half the width of the CCL4 plume. One possible explanation for this is the different time periods of documented disposal of these two compounds at the Propellant Burning

Ground. Concentrations of TRCLE are highest immediately south of the Contaminated Waste Area (maximum concentration of 117 $\mu g/\ell$), and decrease significantly near the base boundary (maximum concentration of 4.7 $\mu g/\ell$) (see Figure 6-32). The vertical extent of TRCLE contamination in groundwater is greater than that for CCL4 (see Figures 6-36 and 6-37). At well cluster PBN-89-10 (south of the Contaminated Waste Area), the TRCLE plume extends more than twice the depth of the CCL4 plume. South of the Propellant Burning Ground, the TRCLE plume is not present in water table wells, which is a phenomenon also observed in the CCL4 plume.

The CHCL3 plume is very similar in horizontal and vertical extent to the CCL4 plume. The main differences are generally lower concentrations of CHCL3 and detections further to the north than CCL4 (i.e., in PBM-89-11 and LOM-91-02).

Detection of 111TCE in groundwater is limited to the north-south oriented line of wells directly south of the Racetrack Area (see Figure 6-32), and is within the bounds of the CCL4, TRCLE, and CHCL3 plumes. 111TCE is detected as far north as well PBN-82-05A and as far south as PBN-89-04 B and C. The plume is relatively narrow (approximately 500 feet wide), with highest concentrations immediately south of the Racetrack Area. From a vertical distribution perspective, the 111TCE plume appears to be limited to the water table well level (or "A" zone) in the north and in the "B" and "C" zones at its southernmost point in well cluster PBN-85/89-04.

6.4.2.5.2 Semivolatile Organic Compounds

Results of analyses for SVOCS and DNTs indicate the presence of 26DNT and NNDPA in groundwater at the Propellant Burning Ground. 26DNT and NNDPA concentrations and are listed in Table 6-19 and shown in Figure 6-38, respectively.

Summary and Interpretation of SVOC Results. The principal SVOC contaminants detected in groundwater were 26DNT and NNDPA. Wells PBN-82-05B and PBN-89-04B were the only locations in which 26DNT was consistently detected (Figure 6-38). 26DNT was detected in only one of the two rounds in wells PBN-82-05A and PBM-85-03. Seasonal variations in precipitation, or sampling and laboratory variations could explain this variability in the data. Groundwater data show that 26DNT has migrated only a fraction of the distance that TRCLE and CCL4 have migrated. Further, it should be noted that the concentrations of 24DNT in subsurface soils beneath the Contaminated Waste Area far exceed those of 26DNT; yet 24DNT was not detected in groundwater.

In contrast to the pattern shown by VOCs, the highest 26DNT concentrations were found deeper in the aquifer in well nest PBN-82-05. This nest is downgradient from the waste pits in the Contaminated Waste Area (and the Racetrack) where DNTs were detected in the subsurface soils. These waste pits represent possible sources of 26DNT in groundwater.

DNTs were not detected in any wells in the Settling Ponds and Spoils Disposal Area. The existing DNT data indicate a localized 26DNT distribution in the groundwater, and based on available data, it appears that DNTs could be entering groundwater in the vicinity of the burning pits and waste areas, but migrating a much shorter distance within the aquifer than the VOCs.

NNDPA distribution in groundwater is very similar to that of 26DNT (Figure 6-38). The maximum concentration of NNDPA detected 25 $\mu g/\ell$, in well PBM-85-03 south of the Racetrack. NNDPA was detected in subsurface soils of the Contaminated Waste Area, which represents possible source for this chemical detected in groundwater.

A more detailed and quantitative description of the distribution of SVOCs at the Propellant Burning Ground, Landfill 1 and Settling Ponds and Spoils Disposal Area is presented in the following section. A summary of inorganics results are presented in Subsection 6.4.2.5.3.

26DNT was detected in wells PBN-82-05A and B, PBM-85-03, and PBN-89-04B. These wells are located south of the Racetrack or Contaminated Waste Area. 26DNT was not observed south of well cluster PBN-89-04. 26DNT was detected sporadically and was not detected in each round of sampling. 26DNT concentrations ranged from less than 1 to 1.39 $\mu g/\ell$. All detects of 26DNT exceeded the WPAL of 0.005 $\mu g/\ell$ and the WES of 0.05 $\mu g/\ell$.

The distribution of NNDPA detected in groundwater samples from the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal

Area is very similar to 26DNT distribution (see Figure 6-38). NNDPA was detected in monitoring wells PBN-82-05A, B, and C, PBM-85-03, PBN-85-02A, PBN-85-04A, PBN-89-04B and C, PBN-89-12B, and PBN-91-12C. Concentrations of detected NNDPA ranged from 0.995 to 25 $\mu g/\ell$. The highest concentrations of NNDPA were observed immediately south of the Racetrack, and detectable concentrations were observed as far south as well cluster PBN-89/91-12.

Other SVOCs (i.e., 2-butoxyethanol [2BUXEL], 2-ethyl-1-hexanol [2E1HXL], and butylbenzylphthalate [BBZP]) were detected sporadically in groundwater at the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area; however, a consistent temporal or spatial pattern was not observed.

The phthalate ester B2EHP was detected infrequently at concentrations up to 382 $\mu g/\ell$ in groundwater, but with no apparent pattern. B2EHP was detected in subsurface soil samples from the Contaminated Waste Area in the Propellant Burning Ground. Although DNBP was reported in the subsurface soil samples at the Propellant Burning Ground, this compound was not detected in the groundwater. Phthalate esters are used as plasticizers and in formulation of smokeless powders; however, they also are frequently introduced as contaminants during well construction or the sampling and analysis process. The analysis results show no spatial pattern of detection near suspected sources. In addition, no consistent temporal pattern was observed for the majority of wells. Therefore, B2EHP is attributed to well construction, sampling, and/or laboratory contamination.

6.4.2.5.3 Inorganics (Metals and Anions)

Several inorganics were detected above background concentrations and/or Wisconsin standards in the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area wells. CD, CR, HG, and PB were the major metals detected above Wisconsin standards in some wells. NIT and SO4 were the anions evaluated. Both anions were detected in groundwater at this site.

PBM-89-11, installed approximately 1,000 feet upgradient from the Contaminated Waste Area, generally provides a good indication of background levels of inorganic chemicals upgradient of the Propellant Burning Ground.

Chemical data for this well and all other monitoring wells in the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area are presented in Table 6-19.

Summary and Interpretation of Inorganics Results. Although CD, CR, and PB were detected in soils at the Propellant Burning Ground, these metals generally appear to be bound in the upper soil layers with minimal migration down to the groundwater. CD, CR, HG, and PB were detected in groundwater at low concentrations in Round One; CR was detected in 53 wells. None of these metals were detected in Round Two. Potential sources of laboratory contamination and error were investigated to explain these metal data, in particular, CR. No definitive sources of laboratory contamination or error were found. In addition, field records were checked and field personnel questioned; standard field sampling practices were followed during both rounds of groundwater sampling. Although definitive conclusions about the source of CR bias have not been reached, the following observations can be made: (1) CR was present in method blank samples during Round One but not Round Two, (2) standard-matrix spike recoveries for CR were higher during Round One (Appendix L), (3) CR was detected in laboratory analyses from monitoring well and production/residential well samples in Round One but not in Round Two, and (4) the same lot of acid preservative used in Round One was also used in Round Two. Given these observations, one potential source of the CR detected in Round One groundwater samples is laboratory bias.

Other metals were detected within background ranges with the exception of CA, which appears slightly elevated in the area of Landfill 1.

NIT in the groundwater at the Propellant Burning Ground appears to be related to agricultural practices at BAAP rather than past production and waste disposal. Off-site agricultural practices may also impact NIT concentrations in groundwater due to the easterly component of groundwater flow upgradient from the Propellant Burning Ground (see Figure 2-3). Analyses of the wells located around Landfill 1 detected NIT concentrations above typical background levels (see Table 6-19). Elevated NIT concentrations were detected deeper in the aquifer in the B series wells, which would indicate a source of NIT upgradient of Landfill 1. The southern area of high NIT concentrations does not correlate with the VOC plume (see Figure 6-39), whose origins are believed to be related to the Propellant

Burning Ground. VOC concentrations increase with depth, while NIT concentrations decrease with depth. If the source areas were similar, the high NIT contamination would show a distribution similar to that of the VOC plume. Near the Settling Ponds and Spoils Disposal Area, the NIT concentrations also do not follow the VOC pattern observed; specifically, the higher NIT concentrations are detected in wells with low VOC concentrations. If earlier disposal of nitrogen-containing wastes contributed to the groundwater NIT contamination, this is not apparent now. The spatial distributions and concentrations of NIT do not indicate that the Propellant Burning Ground is a source of NIT contamination observed in groundwater.

South of the Propellant Burning Ground and north of the Settling Ponds are several USDA research plots and large areas of leased cropland (see Figure 2-9). The highest concentrations of NIT occur in PBM-85-04, PBM-85-05, and S1109 which are in and south of the research plots. Addition of fertilizers and animal manure to cropland would contribute to soil NIT levels. Any NIT not used by plants remains in the soil and is leachable to groundwater. These agricultural practices are likely to be the source of the high NIT concentrations reported south of the Propellant Burning Ground.

One isolated area of SO4 concentrations above the 41,000 $\mu g/\ell$ background is evident in wells PBN-82-05B and PBN-89-01B south of the Propellant Burning Ground. Wells PBN-82-05B and PBN-89-01B are downgradient from potential source areas in the Propellant Burning Ground. It is possible that the elevated concentrations of SO4 detected in groundwater from these wells are attributable to elevated concentrations of SO4 in subsurface soils from the Propellant Burning Ground.

A more detailed and quantitative description of the distribution of inorganics is presented in the following section.

Distribution of Inorganics. At the Propellant Burning Ground, CD, CR, HG, and PB were all detected at low concentrations, and in no case was detection confirmed in both rounds of sampling. CR was detected almost exclusively in Round One in 53 wells. CD was detected in three wells; all detects were exclusive to Round One. PB was detected in both Round One and Round Two, but in no case was PB detected in the same well during both rounds of sampling. HG was detected in two wells; detection was exclusive to Round Two.

CA concentrations appear elevated above background in the vicinity of Landfill 1. With the exception of this anomaly, other metals in groundwater beneath the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Areas are within the range of background concentrations.

NIT concentrations reported from the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area vary from below certified reporting limits to 21,000 $\mu g/\ell$. Table 6-19 lists NIT results from Rounds One and Two for wells in the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area. NIT concentrations in almost all wells exceed the WPAL (i.e., 2,000 $\mu g/\ell$). Background NIT concentrations in groundwater range from 350 to 10,000 $\mu g/\ell$, with four of the seven background monitoring wells containing NIT in excess of the WPAL of 2,000 $\mu g/\ell$.

Figure 6-39 illustrates NIT data for wells with concentrations in excess of the maximum background concentration and the WES of 10,000 $\mu g/\ell$. At Landfill 1, the highest NIT concentrations were detected in the "B" series wells; east of the WWTP, the highest NIT concentrations occur in the water table wells; and, at the base boundary, the highest NIT concentrations occur in the southwest corner of the base and just to the east of the railroad tracks. The distribution of these high NIT concentrations does not match the VOC distribution; this suggests that the NIT contamination is not related to the VOC plume and that source locations are likely different. Agricultural practices in the north, southeast, and west of the Propellant Burning Ground are believed to be the cause of elevated NIT concentrations in groundwater. In addition, off-site agricultural practices may also impact NIT concentrations in groundwater as a result of groundwater flow directions north and northwest of the Propellant Burning Ground.

The average background S04 concentration in groundwater at BAAP is approximately 20,000 $\mu g/\ell$, with a range of 6,200 to 41,000 $\mu g/\ell$ (see Table 2-6). The majority of groundwater samples from wells in the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area exceed the maximum background concentration of 41,000 $\mu g/\ell$, but only groundwater from three wells (PBN-82-05B, PBN-89-01B, and S1133) exceeds the WPAL of 125,000 $\mu g/\ell$. Two of these wells, PBN-82-05B and PBN-89-01B, are directly downgradient from the potential source area of the racetrack, and follow a distribution similar to that observed for VOCs.

> The other water quality parameters measured at the Propellant Burning Ground were TDS, HARD, ALK, and CL. Most wells contained TDS above the WPAL of 250,000 $\mu g/\ell$, and 13 wells exceeded the WES of 500,000 $\mu g/\ell$. Values of TDS in the wells ranged from 40,000 to 621,000 $\mu g/\ell$ in the monitoring wells. Groundwater from the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area wells was also analyzed for HARD, ALK, and CL. The HARD results ranged from 214,000 to 520,000 $\mu g/\ell$; ALK ranged from 178,000 to 481,000 $\mu g/\ell$; and CL ranged from 3,700 to 7,300 $\mu g/\ell$ in most samples. No samples exceeded the 125,000 $\mu g/\ell$ WPAL for CL. No obvious trends were observed from these results.

6.4.2.6 Environmental Fate of Contaminants. The chemical and physical behavior of major contaminants at BAAP are described in terms of how they affect the environmental fate, and especially migration potential, of the contaminants. Table 6-20 lists the organic chemicals considered major contaminants at BAAP and summarizes their chemical and physical properties. The depth to groundwater is relatively great at BAAP (more than 100 feet) and the potential exists for significant *volatilization of many compounds in the soil column.*

C6H6 and TRCLE were the principal VOCs found in subsurface soil at the Propellant Burning Ground. Both C6H6 and TRCLE are sufficiently volatile to evaporate from surface soil and, to a lesser extent, from subsurface soil. Their presence in subsurface soil can be attributed to the burial of solvents, dumping of solvents before burning, and subsequent covering of disposal areas with clean soil. A major pathway for TRCLE is expected to be water transport (leaching) through the soil column to groundwater. TRCLE will then follow groundwater flow. Reductive dechlorination of TRCLE via biological activity under anaerobic conditions to form dichloroethylenes (DCEs) can occur (Vogel, et al., 1987). The predicted environmental half-life of TRCLE in aqueous solution undergoing hydrogenolysis is 0.9 years (Vogel, et al., 1987). Hydrogenolysis is defined as a reduction in which a carbon-halogen bond is broken and hydrogen replaces the halogen substituent. TRCLE degradation compounds in groundwater beneath the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area were analyzed for, but not detected.

Decomposition of C6H6 via microbial action (under both aerobic and anaerobic conditions) is known to be a significant process (Callahan et al., 1979a). Generally, biodegradation is faster in groundwater than in soils. Under aerobic conditions, bacteria initially oxidize aromatics by oxygenases to form a dihydrodiol with a cis-configuration. Further oxidation leads to the formation of catechols and finally to enzymatic fission of the aromatic ring (Cerniglia, 1984; Dagley, 1984). C6H6 was not detected in groundwater at BAAP, suggesting that although found at high concentrations in subsurface soil samples from the Contaminated Waste Area, C6H6 has not reached groundwater or has been biologically transformed shortly after reaching the groundwater.

Although a source of CCL4 in surface and subsurface soils was not clearly identified, the extent of CCL4 in groundwater points to a significant source in the Propellant Burning Ground Area. CCL4 is volatile and will evaporate from surface and subsurface soils to the atmosphere. However, as with TRCLE, the predominant fate of CCL4 is its transport in groundwater. The predicted environmental half-life of CCL4 in aqueous solution undergoing hydrogenolysis is 7,000 years (Vogel, et al., 1987). Biotransformation of CCL4 to CHCL3 has been observed under anaerobic conditions in soil (Vogel, et al, 1987). Eventually, CCL4 will either be degraded, or diluted by dispersion in groundwater to below certified reporting limits.

111TCE was detected at low concentrations in groundwater beneath the Propellant Burning Ground, although no source of the compound was found in surface or subsurface soils. The spatial distribution and low concentrations of 111TCE (see Figure 6-32) suggest that 111TCE is being diluted below certified reporting limits by mixing with groundwater as it is transported south of BAAP. Biodegradation of 111TCE to 11DCLE has been shown to occur under anaerobic conditions in aquifer materials (Vogel, et al., 1987). 11DCLE was not detected in groundwater at BAAP.

CHCL3 was also detected in groundwater beneath the Propellant Burning Ground, Landfill 1, and Settling Ponds. Based on the low K_{oc} of this compound (44), CHCL3 is expected to move more quickly than CCL4 and TRCLE in an aquifer containing organic carbon. Current data suggest that sorption is not an important process in the aquatic fate of CHCL3. The predicted environmental half-life of CHCL3 in aqueous solution ranges from 1.3 to 3,500 years (Vogel, et al., 1987). Ultimately, CHCL3 will either be degraded, or diluted below certified reporting limits by mixing with groundwater as it is transported south of BAAP.

DNTs are moderately water-soluble organic chemicals that were found at high concentrations in the subsurface soil beneath the Contaminated Waste Area. Disposal practices at BAAP probably involved pouring fuel and solvents on the propellant wastes to start burning. These fuels and solvents may have carried DNTs farther down into the soil. C6H6 was also used in the DNT extraction process to reclaim nitrocellulose for use at the Ball Propellant Plant; this is supported by the coexistence of C6H6 and DNTs in the soil column. DNTs were found in subsurface soil probably for several reasons: (1) transport with water or solvents; and (2) burial practices of using fill to cover disposal or burial pits; (3) DNTs are not sufficiently volatile to evaporate from the surface soil to the air.

According to literature values, the partition coefficients for DNTs on organic carbon from water solution, K_{oc}, are estimated from their water solubilities to be 45 and 92 milliliters per gram (mℓ/g) for 24DNT and 26DNT, respectively (Arthur D. Little, Inc., 1985; and USEPA, 1986a). These K_{oc} values are smaller than those for TRCLE (126 mℓ/g) and CCL4 (110 mℓ/g), which would imply that DNTs are more mobile in groundwater. Groundwater chemical data indicate this is not the case at BAAP. Assuming that DNTs and TRCLE were disposed of at BAAP during the same period, TRCLE is significantly more mobile than DNTs at BAAP as evidenced by comparison of the distances traveled by each contaminant. A more recent K_{oc} value for 24DNT was calculated from measured adsorption isotherms (Table 6-20) (Ho, 1988). This value is 250 mℓ/g, which is higher than the first estimated value, but still not high enough to explain the observed distribution of 26DNT and the much shorter distance traveled by DNT in groundwater compared to TRCLE. Partition coefficients are affected by the molecular structure of the compound, especially by the presence of very polar groups, such as nitro groups. These groups interact with clays in soil to form bonds via electronic interactions and ligand formation with cationic areas of the clay structure. This property will predominate with decreasing organic matter in the soil and increasing clay fraction. DNTs are very polar and would be expected to adsorb more strongly to clays. Despite the ambiguity in adsorption values for 24DNT and 26DNT, the potential to migrate to groundwater is clear and is borne out by the concentration profiles of the subsurface soil and groundwater data in the vicinity of the Propellant Burning Ground.

The microbiological degradation studies that have been undertaken for 24DNT and 26DNT under both aerobic and anaerobic conditions have yielded conflicting results. There is no experimental evidence that abiotic oxidation or reduction of explosives contaminants occurs under ambient environmental conditions (CH2MHILL, et.al., 1992). However, the biotransformation of DNTs has been studied in laboratory experiments. Transformation products detected included amino and azoxy derivatives (Walsh, 1990).

NNDPA was detected in subsurface soil and groundwater. NNDPA is not expected to volatilize from the subsurface or surface soils. It is moderately soluble in water and, as with DNTs, is expected to be transported with groundwater. The K_{oc} value for NNDPA given in the literature is 650 mℓ/g, which indicates it will sorb to soils more strongly than CCL4, TRCLE, or 24DNT (Arthur D. Little, Inc., 1985). This stronger sorption is reflected in slower movements within the unsaturated zone, groundwater and more localized contamination. NNDPA is not a highly oxidized compound, and is expected to be susceptible to degradation by biological activity. No biodegradation rates for this compound have been published.

The partitioning of the polar aromatic compounds 24DNT, 26DNT, and NNDPA is not well represented by the simplistic relationship for hydrophobic chemicals on the organic matter in soil represented by $K_d = K_{oc} f_{oc}$. The simple model is useful for nonpolar chemicals with limited water solubility (i.e., solubility less than approximately 10^{-3} molar) (Mingelgrin and Gerstl, 1983; and Karickhoff, 1984). Nonhydrophobic interactions between the soil and chemicals are dominant for two cases, highly polar chemicals, especially with very polar or ionizable functional groups (such as the nitro and amino groups on DNT and NNDPA) and soil with low organic carbon content. The aquifer soil at BAAP is expected to contain very little organic carbon and is mostly sand with some silty or clay layers as described in Section 6.3.

B2EHP was detected in subsurface soils from the Contaminated Waste Area in the Propellant Burning Ground. Phthalate esters are used as plasticizers and in the formulation of smokeless powders. However, detection of B2EHP in groundwater samples is attributed to well construction. The fate of B2EHP in the environment may depend largely on the presence of microorganisms in soil and groundwater. Mixed microbial systems are capable of degrading phthalate esters under aerobic conditions. Degradation is generally slower under anaerobic conditions and ceases to be effective for B2EHP (Callahan, et al., 1979a). Mathur (1974) found that phthalate esters are biodegraded in soil. He suggests the mechanism to be some form of hydrolysis by specific esterases. Also, he reported that degradation rates decreased at lower temperatures. Johnson and Lulves (1975), in a laboratory study of fresh water hydrosoil, found that ^{14}C-carbonyl-labeled bis(2-ethylhexyl) and di-n-butyl phthalates were degraded with half-lives of approximately 14 days and 1 day, respectively, under aerobic conditions. Under anaerobic conditions, degradation occurred more slowly or not at all.

The solubility of B2EHP is 0.4 to 1.3 mg/ℓ, which is very low relative to other contaminants detected in soils at the Propellant Burning Ground. The transport of B2EHP from soils to groundwater is likely to be limited by this low solubility.

The predominant contaminants in surface soil at the Propellant Burning Ground are 24DNT, 26DNT, and PB. According to subsurface soil data, PB has not migrated very deeply into the soil, and is not found in the groundwater. PB forms stable insoluble inorganic compounds, but can also react with organic material in soil to form water-soluble compounds (Callahan et al., 1979b). Given the lack of movement observed in the soil column, it is unlikely that, given the current environmental conditions at BAAP, PB will migrate to the groundwater.

In general, the anions NIT and SO4 will percolate through the unsaturated zone to groundwater, and be transported with groundwater, with little retardation due to sorption. SO4, especially during its movement through the soil column, is expected to migrate more slowly than NIT because of the low solubility of many SO4 metal salts. However, once in the saturated zone, the metal concentrations in subsurface soils generally decrease, and less precipitation and retention of SO4 is expected. Even if NIT and SO4 were present as soluble salts when they were buried, dumped, or, in the case of NIT, applied to the soil as fertilizer, migration of NIT would be expected to be faster than SO4, with less retention in the soils.

6.4.3 Summary of Contamination

Organic and inorganic chemicals related to processes used at BAAP have been found in surface soil, subsurface soil, and groundwater at the installation. Some of these chemicals are moving freely with groundwater and have been detected in wells located along the southern boundary of BAAP. The Propellant Burning Ground has the greatest contamination by metals in surface soils, SVOCs and VOCs in subsurface soils and VOCs in groundwater. A large plume of groundwater contaminated with CCL4, CHCL3, and TRCLE has migrated from the Propellant Burning Ground south and off the installation. NIT concentrations in groundwater throughout BAAP exceed or approach groundwater quality standards. In general, agricultural practices rather than plant activities are responsible for the ubiquitous presence of NIT in the groundwater.

At the Propellant Burning Ground, VOCs (primarily C6H6 and TRCLE) were found in subsurface soil of the former Burning Pads and Contaminated Waste Areas. While these areas appear to be the source of VOCs found in groundwater south of the Propellant Burning Ground extending through the Settling Ponds, and further, three points should be noted. First, the most ubiquitous VOC contaminants observed in groundwater are CCL4 and CHCL3, but no specific source of CCL4 or CHCL3 was identified in soil. CHCL3 may be a product of the degradation of CCL4, which is supported by the very similar distribution of the two compounds in groundwater. TRCLE is the next most prevalent VOC, but has not contaminated as much of the groundwater as CCL4 and CHCL3. Second, explosive-related chemicals, 24DNT and 26DNT, were found in surface and subsurface soils in high concentrations. 26DNT has migrated to groundwater downgradient of the Propellant Burning Ground. However, concentrations of 26DNT in groundwater are relatively low, and distribution is not as well defined as that of the VOCs. Third, C6H6 was not detected in groundwater, although a large potential source of this compound was detected in subsurface soil samples from the Contaminated Waste Area of the Propellant Burning Ground.

Metals were found in surface and shallow subsurface soils at the Propellant Burning Ground. The metals have not migrated into deeper subsurface soils or to groundwater. Soils around the Burning Pads and Burning Plates at the Propellant Burning Ground have very high concentrations of PB. Some of these soils contained PB above the TCLP regulatory level.

There are several areas of groundwater where NIT was detected above WES. Because of their spatial distribution in groundwater, they are not considered related to the same source areas as those for VOCs in the Propellant Burning Ground. Agricultural practices in the vicinity of the Propellant Burning Ground, and off-site agricultural practices to the northwest of the Propellant Burning Ground, are believed to be the cause of elevated NIT concentrations in groundwater.

Review of BAAP quarterly groundwater data through September 1992 from Propellant Burning Ground, Landfill 1 and Settling Ponds and Spoils Disposal Areas monitoring wells indicates results are generally in agreement with the RI data. CCL4, TRCLE and CHCL3 are the principle contaminants exceeding the WPAL and the WES. The notable differences between the BAAP quarterly data and the RI data is the detection of very low concentrations (approximately 1 μg/l) of 26DNT in several wells in the two RI rounds of sampling. 24DNT and 26DNT were detected in several Propellant Burning Ground monitoring wells in 1988 and 1989 BAAP quarterly analyses, but were not detected in subsequent quarterly analyses due to an increase in detection limits for these two compounds. Tetrachloroethylene was also reported in BAAP quarterly data, but was not detected in RI analyses. However, tetrachloroethylene was detected in monitoring wells in which other volatile organic compounds (e.g., CCL4, CHCL3, and TRCLE) are identified in the RI. Review of the BAAP quarterly data also reveals four detects of C6H6 in groundwater at the Propellant Burning Ground. However, C6H6 has not been detected since March 1991. CR was detected at concentrations well above background in BAAP quarterly analyses in the summer and fall of 1989. Since 1989, the BAAP database indicates concentrations of CR are at or below background concentrations in the majority of monitoring wells. These data indicate that CR is not a contaminant of concern in groundwater at the Propellant Burning Ground.

6.5 HUMAN HEALTH EVALUATION

6.5.1 Propellant Burning Ground

The Propellant Burning Ground, consisting of two distinct areas totaling approximately 80 acres located in the southwestern portion of BAAP, is described in Subsection 6.1. Landfill 1 is associated with the Propellant Burning Ground. The surface at the Propellant Burning Ground and Landfill 1 has been covered by soil and has been revegetated. It is regularly mowed. The area is adjacent to cropland on three sides; the northern side adjoins a wildlife/open area and a woodland tract.

6.5.1.1 Chemicals of Potential Concern. All chemicals detected in samples of surface and subsurface soil are listed in Appendix O, Tables O-1 and O-2, and include frequency of detection, range of detected concentrations, and rationale for exclusion. The rationale is discussed in Subsection 4.2. Contaminants selected as compounds of potential concern are summarized in Table 6-21.

6.5.1.2 Exposure Point Concentrations. Exposure point concentrations for soil at the Propellant Burning Ground were estimated by applying the calculation procedure described in Subsection 4.3.5. These concentrations are presented in Table 6-21.

Exposure point concentrations for chemicals of potential concern on airborne particulates or as vapor in the area of the Propellant Burning Ground were estimated by applying the calculation procedures described in Subsection 4.3.5 to the soil concentrations listed in Table 6-21. The results of these calculations appear in Appendix O, Table O-6 for the farming scenario, and Appendix O, Table O-8 for the construction scenario.

6.5.1.3 Exposure Assessment. Scenarios evaluated for the Propellant Burning Ground are incidental ingestion of surface soil for a grounds maintenance worker and a farmer. A future resident scenario is evaluated to compare to the former scenarios. In addition, the farming and ground maintenance scenarios consider an inhalation route because of the potential for disturbing the surface soil. Exposure to subsurface soil via oral and inhalation routes are evaluated for a construction worker doing excavation. The Propellant Burning Ground is a large enough area to support crop production activities and is surrounded on three sides by cropland. Factors considered in the selection of exposure scenarios are described in Subsection 4.3.

6.5.1.4 Risk Characterization.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3.4. Chronic and subchronic RfD values employed are shown in Table 4-6; inhalation RfCs are listed in Table 4-9. Detailed calculations of chemical- and route-specific HQ values are shown in Appendix O, Tables O-3 through O-8. HQ values were summed across all chemicals and across all pathways affecting each separate population. The results are shown in Table 6-22. As seen in the table, HI values are below 1.0, indicating that none of the chemicals or pathways evaluated at the Propellant Burning Ground pose a risk of noncarcinogenic health effects from either subchronic or chronic exposures. Although inhalation of particulates and vapors could not be fully evaluated because toxicity values were not available, it is not likely that they would increase HIs to exceed 1.

Cancer Risks. Excess lifetime carcinogenic risks were evaluated as described in Subsection 4.5. Estimates of lifetime average daily intake were derived as described in Subsection 4.3.4. CSFs employed are shown in Tables 4-7 and 4-8 for oral and inhalation exposure respectively. Detailed calculations of chemical-and route-specific carcinogenic risk estimates are in Appendix O, Tables O-3 through O-8.

The results are shown in Table 6-22. Estimated excess carcinogenic risks from exposure to surface soil range from $2\text{x}10^{-6}$ to $8\text{x}10^{-5}$. These risks are within the USEPA target range. For subsurface soil, total estimated excess cancer risk of the ingestion and inhalation pathways for the construction worker scenario was within the target range at $2\text{x}10^{-6}$.

Risks from PB. Because there are no dose-response values for PB, risks from this chemical were evaluated by comparing soil PB concentrations to the interim cleanup level of 500 to 1,000 ppm for PB (USEPA, 1989c). Maximum PB levels of 3,300 ppm in surface soil and 5,371 ppm in subsurface soil exceed the cleanup levels.

6.5.1.5 Summary of Risks at the Propellant Burning Ground. Concentrations of PB in surface and subsurface soils exceed the USEPA target cleanup range. Risk evaluations do not indicate that other compounds contribute to excess risk.

6.5.2 Settling Ponds and Spoils Disposal Area

The Settling Ponds and Spoils Disposal Area, located in the south-central portion of BAAP, consists of Final Creek, four settling ponds, and five spoils disposal sites. The ponds no longer hold standing water, although the area is wet enough to support cattails. The area is fenced off from adjacent pasture land. These areas are described in more detail in Subsection 6.1.3. Characterization of contamination at this site is based on sample analyses from earlier investigations (Ayers, 1984; Envirodyne, 1981; Foth & Van Dyke, 1985) and is discussed in Subsection 6.4.3.4.3. In addition, data from a soil boring made in 1991 to characterize contamination at the outflow area from the wastewater treatment facility into Final Creek was used individually to define a separate exposure area. Data were available for subsurface soil at Final Creek outflow and Settling Ponds 1, 2, and 3. Risks from exposure to contaminants in soil was evaluated separately for each settling pond, spoils disposal site, Final Creek, and the Final Creek outflow area.

6.5.2.1 Chemicals of Potential Concern. Data from one soil boring made in 1991 and from three earlier studies of surface and subsurface soils were used to identify and select chemicals of potential concern for this area (Ayres, 1984; Envirodyne, 1981; and Foth & Van Dyke, 1985). Subsurface soil data was available for the Final Creek outflow area and for Settling Ponds 1, 2, and 3. The subsurface soil data for the Settling Ponds is based on soil borings from which a composite sample was made of soil from zero to 15 feet bgs. The data reports available for subsurface soil are limited and seem to indicate that only a limited number of compounds were analyzed for. This contributes some uncertainty to the use of this data to characterize the area. Lists of detected compounds, detection, frequency, maximum concentration, minimum concentration, and rationale for exclusion as a compound of concern are tabulated in Appendix O as follows:

- Final Creek Outflow Surface Soil - Table O-9

- Final Creek Outflow Subsurface Soil - Table O-10
- Final Creek Surface Soil - Table O-15
- Settling Pond 1 Surface Soil - Table O-18
- Settling Pond 1 Subsurface Soil - Table O-19
- Settling Pond 2 Surface Soil - Table O-24
- Settling Pond 2 Subsurface Soil - Table O-25
- Settling Pond 3 Surface Soil - Table O-30
- Settling Pond 3 Subsurface Soil - Table O-31
- Settling Pond 4 Surface Soil - Table O-36
- Spoils Disposal Area 1 Surface Soil - Table O-39
- Spoils Disposal Area 2 Surface Soil - Table O-42
- Spoils Disposal Area 3 Surface Soil - Table O-45
- Spoils Disposal Area 4 Surface Soil - Table O-48
- Spoils Disposal Area 5 Surface Soil - Table O-51

Compounds selected as compounds of potential concern and their respective exposure point concentrations are summarized in Table 6-23. Exposure point concentrations are maximum detected concentrations because fewer than twenty samples were available in each area. Development of exposure point concentrations is detailed in Section 4.3.5.

6.5.2.2 Exposure Assessment. The exposure routes evaluated for the Settling Ponds and Spoils Disposal Area are incidental ingestion and inhalation of soil for the grounds maintenance worker. The incidental ingestion route for a hypothetical future resident is developed for use as a comparison. Where data for subsurface soil are available, incidental ingestion and inhalation of particulates and vapor are evaluated for a hypothetical construction worker. Because the land is wet enough to support wetland plants such as cattails, it was not evaluated as suitable for a farmer growing crops. Subsection 4.3.4 describes the equations and parameters used to calculate intake for the exposed populations in these scenarios.

6.5.2.3 Exposure Point Concentrations. The exposure point concentrations listed in Table 6-23 are the maximum detected concentrations for each chemical identified as a compound of potential concern in a sub-area. The rationale for selecting exposure point concentrations is described in Subsection 4.3.5. Exposure point concentrations used for the hypothetical construction worker are maximum values for the combination of surface and subsurface soil to a depth of 15 feet bgs, which assumes that excavation will pass through both surface and subsurface soil. The concentrations listed in the columns for subsurface soil in Table 6-23 reflect the maximum value from a zero to 15 feet bgs composite from soil borings. The numbers used to calculate construction worker intake are the maximum values from the combined surface and subsurface columns.

Exposure point concentrations for volatiles and chemicals on PM10 particles are estimated by applying the calculation procedures described in Subsection 4.3.5.

6.5.2.4 Risk Characterization. This subsection describes the risk characterization.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3. Chronic and subchronic RfD values employed are shown in Table 4-6; RfCs appear in Table 4-9. Subchronic RfDs were used for the construction worker scenario; chronic RfDs were used for the grounds maintenance worker and residential scenarios. RfCs were used for construction worker and the grounds maintenance worker inhalation exposures. Detailed calculations of chemical- and route-specific HQ values are shown in Appendix O. These HQ values were summed across all chemicals and all pathways affecting each population. The results are tabulated in Table 6-24. Although the inhalation pathways could not be fully evaluated because of the absence of RfC values for many COCs, the resulting underestimate of the HI is unlikely to be large enough to effect the total HI for ingestion plus inhalation. As shown in the table, no HI value exceeds a value of 1.0, indicating that the chemicals or pathways evaluated at the Settling Ponds and Spoils Disposal Area pose minimal risk of noncarcinogenic health effects from either subchronic or chronic exposures. The HI at Settling Pond 1 is equal to 1.0 based on exposure to 24DNT, but the conservative assumptions of the residential scenario support the conclusion that noncarcinogenic health effects at Settling Pond 1 pose a minimal risk.

Cancer Risks. Excess lifetime cancer risks were evaluated as described in Subsection 4.5. Estimates of lifetime daily intakes were derived as described in Subsection 4.3. Cancer slope factors employed are shown in Tables 4-7 and 4-8 for oral and inhalation routes, respectively. Detailed calculations of chemical- and route-specific cancer risk estimates are presented in Appendix O.

The results are shown in Table 6-24. Estimated maximum excess cancer risks to the exposed populations, including the conservative future residential group, in all areas but Settling Pond 1 fall within or below the target range. At Final Creek outflow, risks range from $7x10^{-8}$ to $2x10^{-5}$. At Final Creek, the range is $1x10^{-6}$ to $5x10^{-5}$; at

Settling Pond 2, $3x10^{-8}$ to $8x10^{-6}$; at Settling Pond 3, $1x10^{-8}$ to $4x10^{-6}$; at Settling Pond 4, no CSFs were available for COCs. In the Spoils Disposal Areas, the ranges were $3x10^{-7}$ to $1x10^{-5}$ at Area 1; $3x10^{-8}$ to $1x10^{-6}$ at Area 2; $3x10^{-8}$ to $1x10^{-6}$ at Area 3; $2x10^{-8}$ to $8x10^{-7}$ at Area 4; and $7x10^{-12}$ to $3x10^{-10}$ at Area 5. At Settling Pond 1, the risk level for the grounds maintenance worker is $5x10^{-6}$ which is within the target range and for the construction worker is $7x10^{-7}$ which is below the target range. The risk level of $2x10^{-4}$ for future residential use, however, is slightly above the target level. Incidental ingestion of soil contaminated with 24DNT contributes 90 percent of this risk with a level of $1.8x10^{-4}$.

Risks from PB. Because there are no dose-response values for PB, risks from this chemical are evaluated by comparing lead concentrations at the site to interim lead cleanup levels of 500 to 1,000 ppm (USEPA, 1989c). Maximum values of PB at the sub-areas of this site range from a maximum of 373 ppm at Spoils Disposal Site 2 to a minimum of 40 ppm in the Final Creek soil. PB was not detected at levels exceeding 500 ppm in any of the sub-areas; therefore, PB does not pose a risk to human health in the Settling Ponds and Spoils Disposal Area.

Evaluation of COCs without Toxicity Values. NC and NG were detected at the Settling Ponds and Spoils Disposal Area but the lack of published toxicity values for either compound prevents a quantitative evaluation of any risk which might be associated with exposure to soil contaminated with these compounds. These two compounds will be discussed qualitatively in the following paragraphs.

NC was detected in the surface soil of each Settling Pond and Spoils Disposal Area in concentrations ranging from 50 μg/g to 60,000 μg/g. A search of sources such as Hazardous Substance Databank (HSDB, 1992), IRIS (USEPA, 1992b), Health Effects Assessment Summary Table (HEAST) (USEPA, 1992c), Sax's Dangerous Properties of Industrial Materials (Sax, 1984), and Casarett and Doull's Toxicology (Klaassen, et al. 1986), revealed little information on the toxicology of NC. A study was reported which identified a NOAEL of 1,800 mg/kg/day for NC using chronic oral administration to rats (Ellis et al., 1978). Applying uncertainty factors as described in HEAST (USEPA, 1992c) of 1,000 (10 for interspecies extrapolation, 10 for intraspecies variation, and 10 for each of additional data) gives a proposed health protective dose of 1.8 mg/kg/day. Calculated daily intake for a child based on the maximum NC concentration of 60,000 μg/g is 0.07 mg/kg/day (see Appendix O, Table O-20). This intake is below the calculated safe dose of 1.8 mg/kg/day. Based on this information, NC does not appear to pose a risk to human health.

NG was detected in one sample of surface soil at Spoils Disposal Area at a concentration of 19 μg/g. Currently, there are no "toxicity values" (RfDs or CSFs) identified for NG. NG has been used for the treatment of angina pectoris. Therapeutic levels may be achieved with tablets for sublingual administration containing 0.4 mg NG. A reported therapeutic dose level ranges from 2.5 to 5.0 mg every 2 to 3 hours, as needed (Poisindex, 1992). Transderm-Nitro transdermal therapeutic system is rated to release 2.5 to 15 mg NG over 24 hours (HSDB, 1992).

Headache, heart palpitations, nausea, vomiting, hypotension and cutaneous flushing may be signs of NG poisoning. Methemoglobinemia may result from the conversion of NG to nitrites in the body. An individual had a methemoglobin level of 7 percent reported following ingestion of 100 tablets of 0.4 mg NG over a 36 hour period (HSDB, 1992). Organic nitrite dependence may result from chronic exposure to NG. Withdrawal from NG may cause cardiovascular disturbances.

There is insufficient data available to accurately assess the acute sublingual or acute oral dose (HSDB, 1992). A health protective level of exposure may be developed based on the therapeutic dose of NG using USEPA methods for developing RfDs (USEPA, 1992c).

If the lowest therapeutic level identified for an adult is 2.5 mg/day, and applying an uncertainty factor of 100 (10 for extrapolating from lowest therapeutic level, LOEL, and 10 for sensitive individuals), a proposed health protective dose level of 0.025 mg/day is developed (2.5 mg/day/100).

For oral exposure to children: If the body weight of an adult is 70 kg, and the body weight of a child is 35 kg, then an additional safety factor of two should be applied (70 kg/35 kg).

Therefore: 0.025 mg/day / (2) = 0.013 mg/day

With a soil ingestion rate of 200 mg/day assumed for children, a health protective concentration of 65 μg/g of NG in soil was calculated for children being exposed. With a soil ingestion rate of 100 mg/day assumed for adults, a health protective level of 250 μg/g of NG in soil was calculated for adults being exposed.

The detected concentration of NG, 19 μg/g, does not exceed either the safe dose for children or for adults. Based on this information, NG does not appear to pose a risk to human health at this site.

6.5.2.5 Summary of Risks at the Settling Ponds and Spoils Disposal Area. Neither the grounds maintenance or construction worker scenarios at any subarea produce cancer risks above the target range. The conservative future residential scenario similarly does not produce risks exceeding the target range at any subarea with the exception of Settling Pond 1 where the excess cancer risk of $2x10^{-4}$ is slightly above the range.

Based on assumed current and future human activities at this area of the BAAP site, there does not appear to be a noncarcinogenic health risk for current or future populations.

6.5.3 Evaluation of Groundwater Quality. Groundwater in the aquifer associated with the Propellant Burning Ground, Landfill 1, and the Settling Ponds and Spoils Disposal Area is discussed in detail in Subsection 6.4.2.5. Table 6-25 summarizes the compounds detected in the groundwater, the frequency of detection and the minimum and maximum detected concentrations. The detected concentrations can be compared to the standards also listed on Table 6-25. Concentrations of CCL4, NIT, 26DNT, CHCL3, TRCLE, and HG exceed MCLs or WESs. Concentrations of beryllium (BE) and NNDPA exceed concentrations calculated to be protective at an incremental risk level of $1x10^{-6}$. Concentrations of CR, PB, and CD are below standards but exceed WPALs. Finally, concentrations of MN and SO4 exceed secondary drinking water standards, while NA exceeds a reporting level for sodium-restricted diets. The distribution and relationship of these compounds to site-related activities is described in Subsection 6.4.2.5.

6.5.4 Discussion of Uncertainties. Uncertainties of the risk assessment process are summarized in Subsection 4.6. Particular uncertainties associated with these sites are the lack of toxicity data for some COCs. Risks associated with ingestion exposure to some of these compounds is evaluated qualitatively but the absence of quantitative values overall may underestimate risk. A second specific uncertainty is associated with the data sets available to characterize the Settling Ponds and Spoils Disposal Areas. The samples were analyzed for a limited number of volatiles and semivolatiles, therefore the COCs identified may be an underestimate.

6.5.5 Summary and Conclusions

Noncarcinogenic risk at the Propellant Burning Ground does not exceed the USEPA Target Risk Level of 1. PB levels in surface and subsurface soils at the Propellant

Burning Ground exceed the interim cleanup level. Carcinogenic risks do not exceed the USEPA target range of 10^{-4} to 10^{-6} for any of the pathways.

Noncarcinogenic risk at the Settling Ponds and Spoils Disposal Area do not exceed the USEPA Target Risk Level of 1. PB levels do not exceed the interim cleanup level. Carcinogenic risks are within USEPA's acceptable range for the exposure scenarios involving current and future grounds maintenance and future construction workers. Carcinogenic risks for future residents exceed the acceptable range only at Settling Pond 1. Here, incidental ingestion of soil contaminated with 24DNT produces an incremental cancer risk of $2x10^{-4}$.

6.6 BASELINE ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment for BAAP is to describe sensitive habitats and natural resource areas throughout the study area, focusing on the ecological communities at each BAAP site under investigation. In addition, baseline ecological effects associated with exposure to chemical constituents in environmental media at the facility are characterized. The ecological assessment for the Propellant Burning Ground, Landfill 1, and Settling Ponds and Spoils Disposal Area, conducted according to procedures outlined by USEPA, contains the following elements (USEPA, 1989a):

- Basewide Ecological Resource Areas (Subsection 2.2.6)
- Site Biological Characterizations (Subsection 6.6.1)
- Selection of Chemicals of Concern (Subsection 6.6.2)
- Ecological Risk Characterization (Subsection 6.6.3)

The general approach used to characterize ecological risk in this Baseline Ecological Assessment is summarized in Section 5.0.

6.6.1 Site Biological Characterizations

No permanent water bodies are associated with the Propellant Burning Ground Area or the Settling Ponds and Spoils Disposal Area, and the settling ponds would be circumvented by a force main to the Wisconsin River if the facility were to return to active status. As a result, only terrestrial organisms will likely be exposed to contamination detected in this section of BAAP. As described in Section 5, and summarized in Tables 5-1 and 5-2, the incidental soil ingestion and consumption of contaminated food pathways are the likely exposure pathways for potential ecological receptors at these sites.

6.6.1.1 Propellant Burning Ground. The Propellant Burning Ground and Landfill 1 are two distinct sites in the southwestern portion of BAAP. The overall area is classified as a plant facility tract within the confines of the plant (Hellewell and Mattei, 1983) and the tract is maintained as improved grounds. The surface at the Propellant Burning Ground and Landfill 1 is covered by soil and is vegetated and mowed regularly. This area is expected to support mammal and bird species such as moles (*Scalopus aquaticus*), field mice (*Microtus pennsylvanicus*), meadowlarks (*Sturnella magna*) and mourning doves (*Zenaida macroura*) (Appendix P, Tables P-3 and P-4).

The area is surrounded by cropland on all but the northern side, which is adjacent to a wildlife/open area and a woodland tract. The cropland supports many species including white tail deer, redwing blackbirds (*Agelaius phoeniceus*), junco (*Junco hyemalis*), and bobwhite quail (*Colinus virginianus*). Studies conducted at BAAP have shown that the white tail deer populations rely on croplands (primarily corn) as a food source (Herron, 1984; Wegner, 1985). The wooded area may include oak and hickory tree species that are expected to provide habitat for many species of mammals and birds (Appendix P, Tables P-1 and P-2). White tail deer, gray squirrels (*Sciurus carolinensis pennsylvanicus*), cardinals (*Cardinalis cardinalis*), blue jays (*Cyanocitta cristata*) and wood ducks (*Aix sponsa*) were observed at BAAP by ABB-ES field personnel, and these species may use the woodland area as preferred habitat. No aquatic receptors occur at this site.

6.6.1.2 Settling Ponds and Spoils Disposal Area. The Settling Ponds and Spoils Disposal Area is maintained as plant facility support. During past operations at BAAP, the four settling ponds received effluents from sanitary and industrial wastewater treatment plants and runoff from the nitroglycerine, rocket-paste, and magazine areas. The settling ponds, which have a total area of 40 acres, served as aeration and settling basins for treating wastewater streams for BAAP. As the facility is in standby status at this time, wastewater production is relatively low and effluent infiltrates or evaporates in the first pond, allowing the other three ponds to remain relatively dry. No water reaches the river under current operating conditions (Tsai et al., 1988). The presence of cattail (*Typha latifolia*) in the basins of these ponds, however, suggests wet conditions do exist during some times of the year. Other wetland plants, such as blue flag (*Iris versicolor*) and various sedges are expected within the Settling Ponds and Spoils Disposal Area, although aquatic macroinvertebrates and fish are absent because of the lack of standing water. ABB-ES field personnel observed marsh hawks (*Circus cyaneus*), pheasants (*Phasianus colchicus*), mallard ducks (*Anas platyrhynchos*), and raccoon (*Procyon lotor*) in the vicinity of the Settling Ponds. All these species, along with others listed in Appendix P, may be associated with and potentially use the Settling Ponds and Spoils Disposal Area as habitat.

Gruber's Grove Bay, located on the Wisconsin River, is immediately adjacent to the Settling Ponds area. Finfish expected in the bay include bass (*Micropterus* sp.), crappie (*Pomoxis* sp.), and sunfish (*Lepomis* sp.). For a more complete list of fish species potentially occurring in this bay, see Appendix P, Table P-5.

Land in the vicinity of the Settling Ponds and Spoils Disposal Area is used for crop production and pasture, but considerable open space exists as well. Species expected to occur in the woodland and game/open areas associated with the Propellant Burning Ground would also be found in the vicinity of Settling Ponds as well.

6.6.2 Selection of Chemicals of Concern

Although incidental ingestion of or direct contact with seasonal surface water at the Settling Ponds and Spoils Disposal Area is a potential route of exposure, no surface water data exist and therefore compounds of concern were not selected for potential aquatic receptors. Consequently, surface soil is the only medium to which ecological receptors could be exposed to site-related contamination. As a result, compounds of concern were only selected for the surface soil medium at both the Propellant Burning Ground and Settling Ponds and Spoils Disposal Area sites.

6.6.2.1 Propellant Burning Ground and Landfill 1. A summary of the surface soil data collected at the Propellant Burning Ground is presented in Table 6-26. Based on the frequency of occurrence, the range of concentrations found compared to normally expected background levels, and other screening criteria, the following compounds of concern were selected: 24DNT, 26DNT, 2MNAP, AS, B2EHP, BAANTR, C6H6, CHRY, CR, CU, DEP, DNBP, FANT, HG, NI, NNDPA, PB, PHANTR, PYR, SE, and ZN. With the exception of SE, the inorganic compounds of concern were detected most frequently in these surface soil samples. However, 24DNT was detected in more than 10 percent of the samples collected.

Because it has been covered with soil and revegetated, no surficial soil samples were collected at Landfill 1. As a result, compounds of concern were not selected for this area.

6.6.2.2 Settling Ponds and Spoils Disposal Area. Summaries of the analytical surface soil data that are available for Final Creek, the individual Settling Ponds, and the Spoils Disposal Areas are presented in Tables 6-27 through 6-36. The frequency of occurrence, background screening concentrations (inorganic constituents), and other criteria were used to select compounds of concern for terrestrial ecological receptors at each of these sites.

Final Creek Area. A summary of the surface soil data collected at the Final Creek is presented in Table 6-27. Based on the screening criteria, PB, SN, NIT, NH3, SO4, 24DNT, 26DNT, DEP, DNBP, DPA, 2NNDPA, and NC were chosen as ecological compounds of concern for the Final Creek site. PB, NIT, and NH3 were detected in all eight samples, and SN in all but one sample. Although all the remaining compounds were detected less frequently, their potential toxicity warranted their inclusion as compounds of concern.

Settling Pond 1. PB, SN, NIT, NH3, SO4, 24DNT, 26DNT, DEP, DNBP, DPA, 2NNDPA, and NC were chosen as ecological compounds of concern for the Settling Pond 1 area (see Table 6-28). Although PB, SN, NIT, and NH3 were detected in nearly all surface soil samples, the organic compounds of concern were detected in less than half the samples.

Settling Pond 2. Table 6-29 presents the ecological compounds of concern chosen for the Ecological Risk Assessment. These include the following surface soil constituents: PB, SN, NIT, NH3, SO4, 24DNT, DEP, DNBP, DPA, and NC. Again, the inorganic constituents were detected more frequently than organic compounds.

Settling Pond 3. PB, SN, NIT, NH3, SO4, 24DNT, 26DNT, DEP, DNBP, DPA, and NC were selected as ecological compounds of concern for the Settling Pond 3 site (see Table 6-30). PB, SN, NIT, and NH3 were detected in all samples, but the remaining compounds of concern were detected only once or twice.

Settling Pond 4. AL, PB, SN, NIT, NH3, SO4, DPA, and NC were selected as ecological compounds of concern for the Settling Pond 4 site (see Table 6-31). AL, PB, and SN were detected in all samples and detected concentrations were significantly elevated above background levels (AL was detected at a maximum concentration of 60,000 μg/g).

Spoils Disposal Area 1. The following surface soil constituents were chosen as ecological compounds of concern for Spoils Disposal Area 1: PB, SN, ZN, bromide (BR), CL, NIT, SO4, CH2CL2, 24DNT, 26DNT, B2EHP, DNBP, DNOP, DPA, NC, and NG (see Table 6-32). The inorganic compounds of concern, DNOP, and NC were detected in all samples.

Spoils Disposal Area 2. PB, SN, ZN, BR, CL, NIT, SO4, CH2CL2, 24DNT, DNBP, DPA, and NC were the selected compounds of concern for the Spoils Disposal Area 2 (see Table 6-33). All compounds of concern except BR, CH2CL2, and 24DNT were detected in all samples.

Spoils Disposal Area 3. PB, SN, ZN, CL, NIT, SO4, CH2CL2, 24DNT, DNBP, DPA, and NC were chosen as surface soil COCs for ecological receptors at the Spoils Disposal Area 3 (see Table 6-34). The inorganic COCs and NC were detected in all samples.

Spoils Disposal Area 4. PB, SN, ZN, CL, NIT, SO4, CH2CL2, 24DNT, B2EHP, DNBP, DNOP, DPA, and NC were chosen as the surface soil COCs for the Spoils Disposal Area 4 (see Table 6-35). The inorganic constituents, excepting CL, were detected in all surface soil samples collected from the Spoils Disposal Area 4.

Spoils Disposal Area 5. Table 6-36 presents the COCs selected for the surface soil medium at this site; compounds include: PB, SN, ZN, BR, CL, NIT, SO4, CH2CL2, DNBP, DNOP, DPA, and NC.

6.6.3 Ecological Risk Characterization

Risks to ecological receptors that may be exposed to site-related constituents at the Propellant Burning Ground and Settling Ponds and Spoils Disposal Area were characterized according to the procedures presented in Subsection 5.5.

6.6.3.1 Risks to Aquatic and Semi-aquatic Receptors. No aquatic receptors are expected to occur regularly in either the Propellant Burning Ground or in the Settling Ponds and Spoils Disposal Area. Consequently, risks to this class of ecological receptor were not evaluated.

6.6.3.2 Risks to Terrestrial Receptors. Potential risk to terrestrial receptors associated with the incidental ingestion of surface soil and from the consumption of contaminated prey was quantitatively evaluated following the procedure described in Section 5. HQs for terrestrial receptors were calculated by comparing the estimated acute and chronic TBDs for each indicator species with the appropriate RTVs. Chronic and acute HIs for each species were derived by summing the HQs for each area; the estimated risks for the Propellant Burning Ground and the Settling Ponds and Spoils Disposal Areas are presented in Tables 6-37 and 6-38, respectively.

Propellant Burning Ground and Landfill 1. Following the classification discussed in Subsection 5.2, ecological receptors that occur at the site are expected to be at risk for acute and chronic exposures. The HIs associated with both acute and chronic exposures exceeded 1.0 and ranged over several orders of magnitude (see Table 6-37). These results suggest that small mammals, such as the short-tailed shrew, are at greatest risk due to exposure to surface soil constituents at the Propellant Burning Ground (HIs for acute and chronic exposures are 5,500 and 111,000, respectively). Under both acute and chronic exposure assumptions, PB accounted for most of the estimated risk to this group of terrestrial receptors (Appendix R, Tables R-31 and R-32). In addition, copper was determined to be a risk contributor to small mammals for chronic exposures. The acute and chronic HIs estimated for this group of receptors are sufficiently high to suggest that impacts are likely.

HIs for the other modeled indicator species are lower than those estimated for small mammals. However, individual meadowlarks (and other birds with similar diets) and garter snakes (and other reptiles) that regularly forage in the vicinity of the Propellant Burning Ground would also likely be impacted (chronic HIs are 2,000 and 6,300 for the bird and snake, respectively). Approximately 90 percent of the overall chronic and acute risk to these receptors is associated with dietary exposure to CU and PB, with ZN accounting for most of the remaining risk (Appendix R, Tables R-31 and R-32).

Settling Ponds and Spoils Disposal Areas. Risks to receptors that occur in this section of BAAP (including the four Settling Ponds, the five Spoils Disposal areas, and Final Creek) have been evaluated separately in this Ecological Risk Assessment; Table 6-38 presents the results of the individual risk characterizations conducted for these sites. Because of the similarities in the overall risk results among these different sites, however, the potential risks will be discussed jointly.

Based on the results summarized in Table 6-38 ecological receptors that occur at the individual sites associated with the Settling Ponds, Spoils Disposal Areas, and the Final Creek Area are expected to be at risk for both acute and chronic exposures. At all sites, small mammals, such as the short-tailed shrew, appear to be at greatest risk from exposure to surface soil constituents. Estimated acute and chronic HIs for this indicator species ranged over several orders of magnitude, but at all 10 individual areas, impacts are predicted to be likely for this type of receptor. PB was consistently found to be the surface soil constituent that accounted for the majority of the overall HI score (Appendix R, Tables R-33 through R-52). The other compounds of concern found to be significant risk contributors include SN and AL (at Settling Pond 4). The acute and chronic HIs estimated for this group of receptors are sufficiently high to suggest that impacts are likely to occur. In all cases, the chronic HIs were of greater magnitude, and as a result, the most likely type of impacts expected in the overall area would be adverse effects on small mammal reproduction. (PB was found to account for most of the HI scores for rodents, and the small mammal RTV for PB is derived from a study in which dam fecundity was the measured endpoint). However, acute lethal effects are also anticipated based on the findings that predicted exposure concentrations are up to three orders of magnitude greater than those required to cause mortality in laboratory populations.

HIs for the other modeled indicator species are lower than those estimated for small mammals. However, small birds and reptiles that regularly forage in the vicinity of the Settling Ponds and Spoils Disposal Area would also likely be impacted (HIs). As was the case with rodents, PB and SN were the soil constituents most responsible for projected risk.

PB appears to be an ubiquitous surface soil contaminant in these sites, being detected in nearly all analyzed samples. In addition, there is relatively little uncertainty associated with the acute and chronic RTVs selected to evaluate the significance of exposure to PB. The toxicological literature available for PB is fairly extensive (Appendix Table Q-4) and there is ample evidence to suggest that PB dosages (normalized to body weight) on the order of 0.1 to 5 mg/kg-day is sufficient to result in adverse effects to a variety of ecological receptors. Estimated PB exposure concentrations for small rodents, considering both direct soil ingestion and indirect exposure to surface soil constituents via food-chain transfer, were typically in the range of 500 - 10,000 mg/kg-day.

SN is estimated to be a significant risk contributor for secondary consumer indicator species (e.g., fox and hawk) at Final Creek and the Settling Pond sites, and this inorganic constituent was also regularly detected in surface soils associated with these sites. Although the toxicological benchmark levels for SN are of the same magnitude as PB, estimated exposure concentrations for primary consumer indicator species (i.e., rodents and small birds) are somewhat lower because SN concentrations were not as elevated as PB. However, food chain transfer of SN is expected to be of greater magnitude than for PB, given the higher BAFs for uptake by prey items of these top predatory species.

The detected AL concentrations are responsible for a significant proportion of the overall estimated risk found at Settling Pond 4, accounting for 80 percent of the acute HIs for the fox and hawk, and approximately 63 percent of the chronic HI for small birds (Appendix R, Tables R-41 and R-42).

At the Spoils Disposal Area sites, ZN and PB typically accounted for over 90 percent of the HI scores; for the top predator indicator species, ZN was often the largest risk contributor. The shift in the relative importance of ZN and PB between primary and secondary species is due to different bioaccumulation factors for these two inorganics.

6.6.4 Ecological Risk Assessment Conclusions

6.6.4.1 Effects on Aquatic Receptors. There is no aquatic habitat associated with either the Propellant Burning Ground or the Settling Ponds and Spoils Disposal Area and no exposures by aquatic organisms are anticipated. In the case of the Settling Ponds and Spoils Disposal Area, the lack of standing water throughout the year inhibits the establishment of a freshwater community. Aquatic habitat would probably develop in these Settling Ponds if the ponds were to regularly receive wastewater discharge following reactivation of the plant, and an evaluation of the potential risks to these organisms would be necessary at that time. Aquatic organisms are known to be sensitive to some of the constituents (e.g., PB, ZN, and 24DNT) detected in surface soil samples collected from the Settling Ponds and they could well become bioavailable were the ponds to become flooded again. In addition, overflow from Settling Pond 4 historically discharged into Gruber's Grove Bay. In the event that the ponds were to again receive wastewater discharge, the potential transport of site-related contamination into the bay and the Wisconsin River would also require an evaluation. However, the settling ponds will most likely be circumvented by a force main to the Wisconsin River for any future production activity.

6.6.4.2 Effects on Terrestrial Receptors. PB is likely to pose the most risk for small mammals at the Propellant Burning Ground due to surface soil exposures at this area, with CU accounting for most of the remaining projected impacts to small mammals and birds, and reptiles. PB was found to be the surface soil contaminant that accounted for the majority of the risk to small mammals at the Settling Ponds and Spoils Disposal Area. Settling Pond 4 contained AL concentrations sufficient to potentially impact large predators such as foxes and hawks if individuals forage regularly in the area. ZN concentrations in the surface soil at the Spoils Disposal Area typically accounted for a majority of the risk to the top predator indicator species, while PB was the more significant risk contributor to primary trophic level species.

Due to the conservative approach used to characterize risk for these areas (Subsection 5.6), potential impacts to terrestrial receptors are projected for inorganic surface soil concentrations within the range of naturally occurring background levels. Although warranted in a baseline assessment (and particularly until a survey of species of special concern has been conducted), the considerable uncertainties associated with estimating exposure concentrations and toxicological effects may have resulted in ecological risks being overestimated. Field studies to quantify actual exposure concentrations (e.g., biological tissue analysis) and toxicological effects (e.g., bioassays) would provide more accurate information on risk model assumptions and would reduce these inherent uncertainties.

6.7 CONCLUSIONS OF THE BASELINE HUMAN HEALTH AND ECOLOGICAL EVALUATION

6.7.1 Propellant Burning Ground

Based on the results of the human health evaluation; remedial action objectives aimed at reducing concentrations of, or exposure to, PB in surface and subsurface soil should be developed as part of the FS.

The ecological evaluation indicates that remedial action objectives should be developed in the FS to reduce concentrations of, or exposure to, PB, CU, MG, SE, and ZN in surface soil.

6.7.2 Settling Ponds and Spoils Disposal Area

Remedial action objectives based on human health are not necessary at the Settling Ponds or Spoils Disposal Areas.

The ecological evaluation indicates the need to develop remedial action objectives at Final Creek and each of the Settling Ponds and Spoils Disposal Areas. The objectives should address reducing chemical concentrations or exposure to chemicals. The relevant compounds in each area are as follows: Final Creek - PB, SN, 24DNT, DPA, and SO4; Settling Pond 1 - PB, SN, 24DNT, SO4, and DEP; Settling Pond 2 - PB, SN, and DEP; Settling Pond 3 - PB and SN; Settling Pond 4 - PB, SN, and AL; Spoils Disposal Area 1 - PB, SN, ZN, DPA, and NG; Spoils Disposal Areas 2 through 5 - PB, SN, and ZN.

6.7.3 Groundwater

Based on a comparison of groundwater concentrations to state and federal standards, and calculated protective concentrations, remedial action objectives should be developed in the FS to reduce exposure to or concentrations of 26DNT, CCL4, CHCL3, BE, NNDPA, HG, NIT, and TRCLE in groundwater.

7.0 DETERRENT BURNING GROUND AND EXISTING LANDFILL

The Deterrent Burning Ground and Existing Landfill are disposal facilities located near one another in the northeastern corner of BAAP. Since they share similar geologic and hydrogeologic environments they are discussed together in this section.

7.1 CURRENT AND PAST DISPOSAL PRACTICES

7.1.1 Deterrent Burning Ground

The Deterrent Burning Ground is an inactive disposal site in the northeastern portion of BAAP (Figure 7-1). This site occupies an approximate 2-acre man-made depression about 20 feet deep. The approximate shape and location of the depression is shown in Figures 7-1 and 7-6.

The Deterrent Burning Ground was used for the open burning of deterrent, structural timbers, asphalt shingles, cardboard, papers, and office waste. Deterrent is a liquid extract of organic material used to modify the burning characteristics of NC. From 1966 through 1968, and 1971 through 1975, NC was reclaimed from unusable cannon propellant by C6H6 extraction. This process generated a liquid waste that included deterrent which was poured into waste pits and ignited. An analysis of the deterrent reported by Kneessy showed a typical composition containing 73.9 percent DNTs, 20.6 percent DNBP, 2.2 percent DPA, and 3.3 percent C6H6 and insolubles (Kneessy, 1976). According to interviews with former BAAP employees, approximately 500 gallons per week of deterrent was dumped in pits located in the south burning ground (Propellant Burning Ground) from 1966 to 1970. After 1970, deterrent was dumped and burned at the north burning ground (USATHAMA Report No. 111, May 1977). Pits apparently used to burn deterrent were found to contain a layer of hard black ash about 12 inches thick, underlain by silty sand (Kneessy, 1976; Warzyn, 1982b; Kearny, 1987; and Piercy, 1977).

The Deterrent Burning Ground site existed as a borrow pit from the 1940s until the early 1960s (Whitten and Sjostrom, 1988). The historical configuration can be traced using aerial photographs from the period. Aerial photography provided by BAAP, USEPA, and the National Archives, was reviewed for the years 1944, 1949, 1955, 1962, 1968, 1974, 1978, and 1986. Figure 7-2 depicts the development of the Deterrent Burning Ground as observed in the aerial photographs. The western portion of the borrow pit reportedly was used during the 1960s for burial of construction rubble, trash, and burned garbage (see Figure 7-2). Aerial photographs confirm that the western portion was filled and covered from 1962 through 1978. The overall borrow pit area was approximately 5 acres in 1949. However, by 1978, approximately 3 acres had been filled and covered, leaving the approximate current configuration (see Figure 7-1).

As reported in the MEP, records conflict about the exact location and number of deterrent burning pits, particularly the location of a third pit (Tsai et al., 1988). Interviews with plant personnel and review of BAAP operating history confirmed that deterrent waste burning in this area occurred only after mobilization for the Vietnam Conflict, specifically 1971 to 1975. The western portion borrow pit reportedly was used for burning installation trash and was the primary solid waste disposal site during the early 1960s while the plant was inactive. The aerial photographs indicate the western portion of the site was substantially filled prior to deterrent burning.

The 1944 aerial photographs show activity in the borrow pit that appears to be associated with extraction of borrow material. In 1949, the photographs indicate some additional borrow extraction activity, but clearly show some unidentified mounded material and debris on the floor of the borrow pit. The 1955, 1959, and 1962 aerial photographs show activity on the floor of the western half of the borrow pit that appears to be associated with burning. No activity is seen in the eastern portion of the borrow pit in these photographs. In the 1962 aerial photograph, some material (i.e., containers and/or lumber) is visible immediately south and outside the borrow pit. Partial filling of the western half of the borrow pit is visible in the 1968 photograph. Lumber and other unidentifiable objects are seen stored immediately south of the borrow pit. The 1974 photographs show the outline of the pit in approximately its current topographic configuration with essentially all of the western portion of the borrow pit filled. The 1974 photographs also show three distinct areas of activity within and around the northern and eastern perimeter of the existing pit floor. These three areas are interpreted to be the three deterrent burning pits. The approximate location of these three areas is shown in Figure 7-2. In addition, the 1974 photographs show end-dumped, dark mounded material over the filled area at the western end of the original pit area. This dark material may be coal bottom ash from the BAAP power plant.

A 1978 aerial photograph shows the area in approximately its current topography. In this photograph, a pit-like area is visible in the northwestern quadrant of the depression. The three pits evident on the 1974 photograph are no longer clearly visible. Dark-toned material is shown in the western and central portion of the existing depression. Additional fill has also been added to the western half of the depression.

The Environmental Assessment for Total Plant Operations indicates that the Deterrent Burning Ground (termed Landfill 3 in that report) was closed in 1972 (Hellewell and Mattei, 1983). However, aerial photographs show active use of the Deterrent Burning Ground in 1974. The Hellewell and Mattei report further states that deterrent burning was conducted in the eastern portion of the site (comprising less than 10 percent of the area) and that the burning pits were closed by capping with a plastic membrane covered by 3 feet of earth (Hellewell and Mattei, 1983). This closure method was confirmed by BAAP during ABB-ES' initial site reconnaissance. Locations of the pits in that report corresponds to the locations of the pits observed in the 1974 aerial photograph.

It is unlikely that deterrent was burned in the filled area west of the current depression because this area was filled when deterrent burning operations are reported to have begun at the Deterrent Burning Ground. Two of the three former deterrent burning pits were located with soil borings DBB-82-02 and DBB-82-04 which were drilled in previous investigations (Figure 7-3). Soil chemical data from these two borings indicate the existence of significant concentrations of deterrent chemicals; however, no significant concentrations of deterrent chemicals were detected at the locations of DBB-82-01 and DBB-82-03, shown in Figure 7-3. Borings DBB-91-01, DBB-91-02, and DBB-91-03 were drilled near the center of the waste pits to further define the nature and extent of deterrent chemicals at these locations.

7.1.2 Existing Landfill

The Existing Landfill is located in the northeastern corner of BAAP (see Figure 7-1). The landfill, in existence since BAAP was built, was closed in the spring of 1989. Whitten and Sjostrom interpreted existing aerial photographs and concluded that the landfill existed as an open pit by 1949; however, little landfilling or use was evident at that time (Whitten and Sjostrom, 1988). This landfill received essentially all the uncontaminated (i.e., nonpropellant) waste generated at BAAP, including wastes from administrative offices, security-guard quarters, firehouses, and limited operations in the laboratories. Waste insulation, which likely contained asbestos, was also reportedly disposed of in the Existing Landfill. Aerial photographs are available for the years 1944, 1949, 1955, 1962, 1968, 1978, and 1986. Figure 7-4 depicts the development of the Existing Landfill as observed in these aerial photographs. Based on a visual examination of 1968 aerial photographs, it appears likely that coal ash wastes from the BAAP steam plant were disposed of there as well. However, no hazardous or propellant wastes were reportedly disposed of in the landfill. As of 1974, about half the 15-acre landfill site was filled (see Figure 7-4). The remainder of the site consists of a partially excavated pit down to 20 feet bgs. Reportedly, as waste was brought to the Existing Landfill, it was spread out, compacted, and covered with a layer of soil (EEI, 1981; Warzyn, 1982a; Foth & Van Dyke, 1986; Fordham, 1987b; and USATHAMA, 1977). The maximum estimated boundary of the Existing Landfill, based on a review of aerial photography, is shown in Figure 7-4.

The EA for the Existing Landfill states that the facility was in use since 1972 and that fill consisted of nonhazardous materials (Hellewell and Mattei, 1983). Dimensions given were 100 by 800 feet, with a depth of 20 feet.

The changes and identifiable activities observed in the aerial photographs are schematically shown in Figure 7-4. Review of the aerial photographs and comparison of the photographs to one another indicates that activity varied from use as a sand and gravel borrow source in 1944 to use as a general purpose landfill during the 1960s. The photographs reveal changes in the size and depth of the site; however, they do not show the specific activities occurring. This type of detail can only be inferred based on the installation's status at the time an aerial photograph of the site was taken, and what has been found in historical documents, previous investigations of the Existing Landfill, and discussions with existing and former BAAP employees.

Based on the 1955 photographs, the Existing Landfill was apparently used from 1949 to 1955. The 1962 aerial photographs indicate that periodic use might have occurred from 1955 to 1962. Aerial photographs indicate active use again from 1968 to 1989.

The Existing Landfill was closed by capping in 1988. The landfill cap consists of 2 feet of compacted silty soil overlain by 6 inches of topsoil. A grass cover has been established on the top soil layer. Final grades on the cap consist of 4:1 (25 percent) sideslopes and 4 percent top slopes.

As described in Subsection 1.3, a geophysical survey was performed at the Existing Landfill in the fall of 1987 to detect and estimate migration of a suspected contaminant plume, and to locate additional monitoring wells to characterize an SO4 plume identified by previous investigations (Whitten and Sjostrom, 1988).

The geophysics program consisted of EM induction earth resistivity surveys (vertical and horizontal). Fourteen electrical anomalies were identified in that program. The landfill was found to show significant conductivity and resistivity contrast compared to the surrounding soil. Anomalies suggesting highly conductive groundwater were observed in locations ranging from east to south of the Existing Landfill and southeast of the wells that historically have shown SO4 contamination (S1134 and S1135). Based on these data, Whitten and Sjostrom recommended placing at least five additional monitoring wells in the area to estimate the extent and path of contaminant migration (Whitten and Sjostrom, 1988).

7.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

The following subsections present the RI field program undertaken by ABB-ES at the Deterrent Burning Ground and Existing Landfill. A summary of the RI field program is presented in Table 7-1. Conduct of the field program was specified in the following documents: (1) Sampling Design Plan (Data Item A004), (2) QC Plan (Data Item A006), and (3) HASP (Data Item A009).

7.2.1 Soil Vapor Survey

In October-November of 1988, NERI conducted a Petrex Soil Gas Survey at the Deterrent Burning Ground at BAAP. NERI's standard operating procedures for applying the petrex technique to environmental soil gas surveys are described in Appendix B, which contains information on laboratory collector preparation, field operations, collector analysis, mass spectrometer analysis and QC measures, data interpretation and presentation, and interpretation of Petrex maps.

NERI utilized a passive soil gas sample collection system wherein the sample collectors were installed at a sample location 1 to 3 feet bgs and were retrieved at a later date for analysis.

A total of 110 collectors (Numbers 136 through 245) were installed at the Deterrent Burning Ground at approximately 30- to 50-foot intervals. The array of 110 soil gas collectors, shown in Figure 7-5, was designed to (1) locate three previously closed and capped deterrent burning pits, (2) determine whether a source of VOCs exists upgradient of monitoring well DBM-82-02, and (3) locate other potential sources of VOCs in the filled western portion of the Deterrent Burning Ground. Forty-nine collectors were placed in an L-shaped grid covering the northern and eastern halves of the flat-bottomed depression; an additional five collectors were evenly distributed in the remaining southwestern quadrant of the pit. Eight collectors were distributed crossgradient, upgradient, and downgradient of DBM-82-02. Forty-eight collectors were evenly distributed on an approximate 50-by-50-foot grid over the filled western portion of the Deterrent Burning Ground.

7.2.2 Remote Sensing Geophysics

Geophysical surveys were conducted by ABB-ES at the Deterrent Burning Ground. The purpose of the surveys was to locate former pits in which deterrent burning occurred. Information derived from these field activities was used for planning the locations for soil borings. The geophysical techniques applied at the Deterrent Burning Ground included TC and GPR. The principles and applications of these geophysical techniques are described in Appendix C.

Before starting fieldwork, a 100-by-100-foot survey grid was established in the Deterrent Burning Ground to serve as horizontal control for the geophysical measurements. The survey grid, established with a compass and fiberglass tape, was referenced to existing landmarks such as monitoring wells and roads, as appropriate.

A Geonics EM-31DL TC Meter was used for the survey. Measurement stations were established every 20 feet within the survey area, and all stations were referenced to the 100-by-100-foot grid. Measurements were recorded on a digital data logger, and included both the quadrature-phase and in-phase components of the induced magnetic field. The quadrature-phase component gives the TC value in millimhos per meter. The in-phase component, used primarily for calibration purposes on the EM-31, is significantly more sensitive to metallic objects and, therefore, is useful for looking for buried metallic objects (e.g., tanks and drums). Data from the in-phase component is equivalent to a metal detector survey. The survey coverage for the study area is indicated in Figure 7-6.

GPR measurements also were taken at the Deterrent Burning Ground in those portions of the site where historical records and aerial photographs revealed former pit locations for burning activities. GPR traverses were made at 10-foot intervals in these locations. Figure 7-6 shows locations of the traverses made in three separate areas within the Deterrent Burning Ground.

7.2.3 Soil Borings and Subsurface Soil Sampling

During the RI, three soil borings were drilled at the Deterrent Burning Ground from October 15 to 16, 1991, by John Mathes and Associates of St. Louis, Missouri, under subcontract to ABB-ES. The three soil borings (i.e., DBB-91-01, DBB-91-02, and DBB-91-03) were drilled at the Deterrent Burning Ground to further investigate and confirm the location of the three suspected former deterrent burning pits and to characterize the type, concentration, and vertical distribution of contaminants associated with them (Figure 7-1). A summary of the three borings is presented as Table 7-2. Final locations of the borings were determined using data from the geophysical and soil vapor surveys, in coordination with USATHAMA. Each of the three borings was advanced to the water table, encountered at approximately 110 feet bgs. Table 7-3 describes the numbers and types of chemical analyses completed for the subsurface soil samples.

7.2.4 Monitoring Well Installations

Over the course of the RI field activities, a series of 21 monitoring wells were installed at 16 Deterrent Burning Ground and Existing Landfill locations by Layne Environmental of Tempe, Arizona, under subcontract to ABB-ES. These wells supplemented the existing network of 20 monitoring wells previously installed at 10 locations between the two sites. Installation information and siting rationale are summarized in Table 7-4. Figure 7-1 shows the locations of the monitoring wells at the Deterrent Burning Ground and Existing Landfill. Borings for the monitoring wells installed during this RI were typically completed with dual wall driven casing, employing reverse air circulation for cuttings return. Several shallow well borings were drilled with 6.25-inch HSAs.

Monitoring wells installed during the RI include shallow water table wells with screens positioned to straddle the water table and deep monitoring wells with screens positioned approximately 20 to 35 feet below the water table. Wells were constructed with flush-threaded, 4-inch diameter, Schedule 80 PVC with 5-, 10- or 20-foot well screens. Ten- and 20-foot well screens were used for shallow wells and 5- and 10-foot well screens were used for deep well screens. Well screens have 0.010-inch machine slotted openings.

Sandpack material placed around the well screen extends approximately 5 feet above the top of the screen. A bentonite seal was placed above the sandpack. In the deep wells, this seal consisted of a bentonite slurry. In the shallow wells, this seal consisted of a bentonite pellet seal. Above the bentonite seal Type II cement bentonite grout was placed to the ground surface to complete the well installation. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated to 4 feet into the cement-bentonite grout. A coarse 1- to 1.5-inch diameter stone blanket (6 inches thick) was then placed around each protective casing.

Split-spoon samples were generally collected at 10-foot intervals from selected monitoring well borings advanced with HSAs. Soils recirculated through the annulus of the 9-inch dual-walled casing were also sampled at 10-foot increments. At each monitoring well location, soil samples from the deepest boring were visually inspected and logged to record the geologic conditions. At ELM-91-10 split-spoon samples were continuously collected over the bottom 20 feet of the boring to better assess geologic conditions.

The new wells at each site are identified with a letter prefix, ELM or DBN, where EL and DB indicate the site (i.e., Existing Landfill and Deterrent Burning Ground, respectively), M indicates a single monitoring well, and N indicates a group of nested wells. The number 89 or 91 indicates the year the well was installed. Well screen designations A, B, C, and D represent progressively deeper installation intervals; that is, a well number without a letter suffix (e.g., 89-01) or a well number with an A suffix (e.g., 89-01A) represents a water table well. The B suffix (e.g., 89-01B) represents an intermediate level well, while the C and D suffixes represent progressively deeper well-screen intervals.

Well installation diagrams with associated boring logs are in Appendix D. Grout was allowed to set for a minimum of 48 hours before the wells were developed. Well development, accomplished using a submersible pump, consisted of pumping the well while raising and lowering the pump through the screened section of the well. A minimum of five standing water well volumes were removed during the development process. During some well installations it was necessary to add water to reduce the effect of sand entering the drill casing. In these cases, a volume of water estimated to be equal to three times the water added during drilling was removed in addition to the five well volumes. Appendix D contains records of well development activities.

Five water table wells were installed at the approximate locations shown in Figure 7-1 (ELM-89-01, ELN-89-02A, ELM-89-03, ELN-89-04A, and ELM-89-05). After development, samples from these wells were analyzed in the field for conductance, NIT, and SO4 using a Hach® DR 100 Colorimeter. Based on those results, six additional wells (intermediate wells and water table wells) were then installed at locations ELN-89-02B, ELN-89-04B, ELN-89-06B, ELM-89-07, ELM-89-08, and ELM-89-09. Finally, three additional wells were installed at locations ELM-91-10, ELN-91-07A, and ELN-91-07B. These three wells were originally planned to be installed off-post. However, right-of-entry agreements could not be negotiated. As a result, the three monitoring wells were installed along the northeast base boundary at locations less desirable than those off-post, east of BAAP. These wells were designed to enhance both horizontal and vertical definition of the contaminant plume, as interpreted from field analytical screening results.

7.2.5 Borehole Geophysics

A geophysical logging program was conducted at BAAP by Colog, Inc. (Colog), of Golden, Colorado, under the coordination and supervision of ABB-ES. The purpose of this program was to further investigate and characterize subsurface geology at the Deterrent Burning Ground and Existing Landfill as part of the RI program. This was undertaken to support geologic findings which were based on disturbed soil cuttings obtained from the dual-wall driven-casing drilling technique. Generally, the geologic findings from the bore-hole cuttings correlated with the borehole geophysical results. This program consisted of field geophysical log acquisition and interpretation of 12 PVC-cased monitoring wells to a maximum 149 feet in depth. The logged wells included 1989 series wells drilled with hollow-stem augers and dual-wall driven casing and 1982 series wells drilled with mud rotary. Construction diagrams for these wells are included in Appendix D. Table 7-5 summarizes each monitoring well logged during the borehole geophysical program.

The logging suite consisted of natural gamma, non-focused gamma-gamma density, dual gamma-gamma density, neutron, and induction. Additionally, a single-arm caliper log of the casing was collected with the dual-density measurement. Logging methods, field operation procedures, QA, log processing, and log interpretation are described in Appendix E. For each well, log measurements were analyzed with respect to geologic sample descriptions from the drilling process and borehole completion descriptions. Borehole geophysical logging equipment included a Model 2500 and an EM-39, manufactured by EG&G Mt. Sopris Instrument Company and by Geonics Limited, respectively. All data were collected digitally with Colog's data acquisition system and a portable personal computer. Subsequent processing and display of the data were completed with Colog software. All data were collected at 0.5-foot intervals, except for induction data, which was collected at 0.2-foot intervals and then processed with appropriate equations to 0.5-foot intervals.

Radioactive logging probes were lowered to the bottom of each well; digital and analog records were made as the probe was brought to the surface. The induction logging probe was recorded when lowered in the well and when pulled back to the surface. Analog data were used on site to confirm that the probes operated correctly. Digital data were processed and graphically presented and used for the interpretation. Logs from the different probes were aligned at a common elevation and scale for composite presentation in the interpretation.

The logs are used to assist in determining site geology and lithology in the well bore and to identify anomalies reflecting well construction imperfections, such as voids or gaps in the grout behind the well casing. Quantification of formation density and porosity was examined from the log data. However, the presence of grout materials in the well bore resulted in only bulk approximations of these parameters. Hydrogeologic information such as fluid saturation was also inferred from the logs and correlated with geological description boring logs.

7.2.6 Permeability Testing

To obtain an assessment of permeability variations within the unconsolidated aquifer at the site, a series of rising-head slug tests was performed on 18 new and four existing monitoring wells at the Deterrent Burning Ground and Existing Landfill. This included 16 shallow water table wells and six deep monitoring wells. Water displacement for the rising-head tests was accomplished by pressurizing the well casing of deep monitoring wells screened entirely below the water table and by physical displacement of water with a cylindrical slug for monitoring wells with screens intersecting the water table. In the deep monitoring wells, the water column was typically depressed from 2 to 9 feet by sealing the well casing at the wellhead and pressurizing the well with compressed breathing air. Precautions were taken to ensure that air was not forced into the aquifer by lowering the water level into the screened section of the well. This was accomplished by placing an electronic water level probe above the well screen to alert the operator when the water level was approaching the screen interval. The water level was allowed to return to a static condition after releasing the air pressure. In shallow monitoring wells, the water column was depressed by displacing water with a 2-inch diameter cylinder lowered 5 to 8 feet below the static water level. After allowing the water level to recover to its static condition, the slug was quickly withdrawn. As the water rose to its static level, data was gathered for the rising-head test.

The rate of water level rise was recorded with a 20-psi pressure transducer and Hermit 2000 data logger, both supplied by In-situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which can result in water level rebound above the static background level where hydraulic conductivities are high.

Generally, two to five tests were performed on each well to assess the variations associated with each test, evaluate any inertial effects associated with each well, and apply the maximum stress possible at each well. The test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected tests were also analyzed by the Bouwer and Rice (1976) technique (see Appendix I). Results of the Bouwer and Rice analyses compared favorably with Hvorslev results. Results of the Hvorslev analyses are summarized in Subsection 7.3.3.

7.2.7 Groundwater Sampling

Table 7-6 lists the 41 monitoring wells sampled during the RI at the Deterrent Burning Ground and Existing Landfill. Locations of all sampled wells are shown in Figure 7-1.

As part of the RI, ABB-ES conducted two rounds of sampling and analyses on these wells. Round One was conducted from November to December 1991, and Round Two was conducted during April to May 1992. Table 7-7 summarizes, by site, the parameters and analyses completed on the groundwater samples collected during the two rounds of sampling. The specific groundwater sampling procedures followed are described in the BAAP RI Sampling Design Plan developed by ABB-ES, and reviewed and approved by USATHAMA, WDNR, and USEPA (E.C. Jordan Co., 1989 and 1990c).

Before groundwater sampling, the water level and well depth in each well were measured to the nearest 0.01 foot and 0.1 foot, respectively. Water level data are in Appendix G and discussed in Section 7.3. Following these measurements, the new and existing wells were purged with a submersible pump. Purge volumes varied depending on well recharge rates. Generally, five times the sandpack and well volume were purged before sampling, although at several 1982 series wells where the recharge rates were slow, the wells were purged dry. In these instances, additional purging was not needed. Variances were documented and recorded on field data sheets found in Appendix G. Purge water and groundwater samples were monitored in the field at the time of collection for temperature, pH, and specific conductance. During the groundwater sampling effort, field sampling equipment was decontaminated by steam-cleaning with water from Production Well No. 2. Following sample collection, preservation, and packing, all groundwater samples were shipped to A.D. Little in Cambridge, Massachusetts (a USATHAMA-certified laboratory) for the various analyses specific to each site.

7.2.8 Summary of Chemical Analysis Schedule

Subsurface soil samples from the Deterrent Burning Ground as well as groundwater samples from the Deterrent Burning Ground and Existing Landfill were selected for laboratory analysis. The following subsections summarize the chemical analysis schedule.

7.2.8.1 Laboratory Analytical Program. The analytical program for subsurface soil and groundwater is presented in Tables 7-3 and 7-7. The following discrepancies between the Sampling Design Plan and actual sampling tasks have been noted:

- At boring DBB-91-01 two additional samples were collected to better characterize the nature and distribution of contamination observed in soil samples from this boring.
- Well ELN-89-02A was not sampled during Round One due to a lack of water in the well casing.

ABB-ES' analytical subcontractors A. D. Little, EA, and DataChem, used procedures consistent with the USATHAMA CLASS program for analysis of groundwater, soil, surface water, and sediment samples. Several general water quality parameters (e.g., HARD, total ALK, and TDS) did not require certification under the USATHAMA program. Reference information about the USATHAMA analytical methodology is contained in Appendix L. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings with certified reporting limits. Chemical analytical methods are described in Subsection 4.2 of the Sampling Design Plans. A list of chemical analytical methods used by each laboratory are presented in Appendix L.

The analyte matrix is based on the soil and water chemical data presented in the MEP, and the substances reportedly burned and disposed of at the Deterrent Burning Ground and Existing Landfill (Tsai et al., 1988). Because of the potential for elevated metals to limit disposal options for soils at these locations, selected samples were submitted for analysis of TCLP extractable PB, CD, CR, and HG. Results of the TCLP analyses being promulgated for evaluation of toxicity as a component of RCRA (40 CFR 268.7 Appendix I), will be used in this report for estimating the leachable metal concentrations from soil samples.

7.2.8.2 Field Testing. In addition to taking measurements of specific conductance, temperature, and pH at each monitoring well location, 15 existing and nine new wells at the Existing Landfill were field-screened for NIT and SO4. Analyses were performed on site using a Hach® DR 100 Colorimeter. Results of field screening for these inorganic anions were used to locate six additional wells at the Existing Landfill. Results are discussed in Subsection 7.4.

7.2.8.3 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data from A. D. Little, EA, and DataChem and the geotechnical data from the field drilling program.

Appropriate field data records were completed for each groundwater, surface water, and sediment sample (see Appendices D and G). Information such as the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, and sampling technique is recorded. A field notes section provides for any additional site information sampling personnel may need to include. Each well has a Monitoring Well Construction Diagram that documents structural details (Appendix D).

For each soil sample collected, field information was recorded in a field notebook and on a sampling data sheet (see Appendix D). Information such as project name, job number, date sampled, site type, sample depth, site ID, and any pertinent observations are included in this notebook. Field notes also provide for any additional site information the sampling personnel needed to add.

Samples were given unique site IDs that were used for sample identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data has been entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both ABB-ES and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map File, Geophysical Groundwater Stabilized File, Geophysical Field Drilling File, Geotechnical Well Construction File, Chemical Groundwater File, and Chemical Soil File.

Chain-of-custody records along with ARFs were used to coordinate transfer of samples from field sampling locations to the laboratory. Samples were divided into sample lots according to method, matrix, and analytical QC groups.

7.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The Deterrent Burning Ground and Existing Landfill are located approximately two-thirds and three-fourths of a mile east of the Johnstown Moraine, respectively, in the northeastern quadrant of BAAP. The sites are separated by approximately 1,300 feet and share similar geologic and hydrogeologic settings. Therefore, to generate a more comprehensive regional understanding, the two sites are described together in the following subsections.

7.3.1 Surface Water Hydrology

Topographic relief is on the order of 50 feet in the area and is described as irregular knob and kettle, a condition typical of regions behind terminal moraines where stagnant ice melting results in the formation of poorly defined drainage patterns. A small drainage ditch south of the Deterrent Burning Ground extends southward, where it forms the main drainage ditch transporting water from the Nitroglycerine Pond and Rocket Paste Area south to the Settling Ponds and Spoils Disposal Area.

The Deterrent Burning Ground currently occupies a former soil borrow pit approximately 2 acres in area. Historically, the pit occupied a larger area of approximately 5 acres; however, landfilling along the western boundary of the pit reduced the size. The depth of the Deterrent Burning Ground pit ranges from 10 to 30 feet. Surface drainage is contained within the isolated pit, or is routed to the south, where it enters drainage ditches at the road south of the site. Runoff from this area either infiltrates along the ditches or evaporates.

The Existing Landfill, which occupies an approximate 15-acre area, has received waste fill, and currently has a vegetated surface with an approximate 4 percent surface slope to the north. Surface water drainage from the landfill is routed to the northeast beyond the BAAP boundary to a large kettle depression, where the water percolates into the soil and either evapotranspirates or infiltrates to the water table. In accordance with WDNR requirements, the landfill was closed by capping with clay in 1988 to restrict infiltration of precipitation.

7.3.2 Geology

Soil borings and monitoring wells installed at the Deterrent Burning Ground and Existing Landfill encountered approximately 200 feet of unconsolidated soils deposited in association with the maximum advance of the Green Bay Lobe Glacier (Alden, 1918; and Thwaites, 1958). It is estimated that the maximum thickness of unconsolidated soils in this area is on the order of 250 feet.

Generally, the stratigraphic sequence in this area includes a layer of fine-grained silt (i.e., loess), typically 5 to 10 feet thick, underlain by variably textured sand and gravel with discontinuous gravel layers at approximately 50 to 100 feet bgs. Near the water table, a clayey silt to silty fine sand unit was observed in most soil borings at these sites. This fine-grained unit appears to be more discontinuous and coarser textured in the vicinity of the Existing Landfill than in the vicinity of the Deterrent Burning Ground. Finally, coarser textured sands and gravels were encountered beneath the clayey silt unit.

The orientation of geologic cross sections depicting generalized stratigraphic relationships among the outlined units is shown in Figure 7-7. The cross sections are depicted in Figures 7-8 through 7-13. Because of variable geologic conditions encountered in this area, the cross sections only show general relationships interpreted from boring logs and geophysical data. Significant changes can occur among soil borings. Generally, conditions directly observed as borings were drilled were given more weight for geologic interpretations than indirect evidence or geophysical interpretations.

A dark brown to black organic-rich topsoil has developed at the ground surface over a fine-grained silt and clay layer that blankets much of the site. The fine-grained unit is a loess consisting of windblown silt and clay (see Subsection 7.2.3). Boring logs generally indicate this 2-to-8-foot-thick unit is a cohesive brown-to-gray silt and clay with some interbedded sands near the bottom of the unit. The loess appears to be fairly continuous over the area, except for the disturbed and filled areas of the Deterrent Burning Ground and Existing Landfill, where surficial soil was excavated before placement of waste fill and other soil materials (see DBB-91-01, DBB-91-02, and DBB-91-03). The soil borings at the Deterrent Burning Ground encountered soil ranging from fine-to-medium silty sands to clayey silt with soil fill up to 8 feet thick.

Soil boring ELB-82-05, installed within the Existing Landfill, encountered 14 feet of fill materials, including a surficial layer of silty sand underlain by mixed refuse such as wood, paper, asphalt, shingles, cinders, and other waste (Warzyn, 1982a). Engineering plans prepared by Sarko for this installation call for placing up to 25 feet of refuse in the landfill (Warzyn, 1982a). The landfill base appears to be unlined, because only sand and gravel materials were encountered beneath the waste deposits. Variably textured sands and gravels were encountered beneath the loess and fill deposits at the Deterrent Burning Ground and Existing Landfill. These materials typically are characterized as poorly sorted sands and gravels in the upper portions of the unit. The unit generally changes to well-sorted sands and gravels with increasing depth. Substantial quantities of silty sands also were encountered within these units. This sequence appears to reflect reworked glacial till and glaciofluvial deposits.

Below the reworked deposits, a coarse gravel layer was generally observed at a depth of 50 to 80 feet bgs near the Deterrent Burning Ground, and was occasionally encountered beneath the Existing Landfill. This soil appears to be composed largely of glacial outwash and glaciofluvial deposits.

At a depth of 100 to 170 feet bgs, a fine-grained clayey silt unit was encountered in many of the borings installed in the area. Lateral changes in soil texture, as well as laminations and sandy layers within this unit, suggest it was deposited as glaciolacustrine sediment in a lake bottom environment. This unit appears to be laterally extensive in the northern portion of BAAP east of the terminal moraine, as it was encountered in boring S1132 as well as BAAP Production Well No. 4 and the monitoring wells near the Deterrent Burning Ground and Existing Landfill.

At S1132, the glaciolacustrine unit was described as layers of clayey sand with a top surface elevation of approximately 780 feet MSL and a maximum thickness on the order of 14 feet. At Production Well No. 4, the lacustrine unit is described as a "light pink, dolomitic clay" with a top surface elevation of approximately 790 feet MSL and a 15-foot-thickness (Wisconsin Geological and Natural History Survey, 1970). At the Deterrent Burning Ground, the glaciolacustrine unit was typically described as a gray silty clay and clayey silt with a top surface elevation of 750 to 800 feet MSL and a total thickness of 3 to 25 feet. The glaciolacustrine unit is less well-defined in the area of the Existing Landfill and appears to grade from a clayey silt to a silty sand from west to east, with a top surface elevation of approximately 750 to 800 feet MSL and a total thickness of 5 to 15 feet. Generally, the glaciolacustrine unit was not clearly encountered to the southeast of the Existing Landfill near borings ELM-89-03, ELN-89-06B, and ELM-89-07. In this area, fine lacustrine soils appear to grade to fine silty sands approximately 25 feet higher in elevation.

The fine-grained glaciolacustrine unit was also identified by the borehole geophysics program, which indicated a generally thicker deposit of fine-grained clay-like material than was observed in cuttings from the dual-wall driven casing drilling rig. A contour plan characterizing the top surface elevation of the clayey silt layer was prepared from the borehole geophysical interpretations. This contour plan indicates a general anticlinal form with the axis trending generally north-south through the east-central portion of the Deterrent Burning Ground (Figure 7-14). This interpretation is generally consistent with observations from soil borings at the site, although discrepancies occur between conditions observed in soil borings and the geophysical interpretations. Where discrepancies occur, more interpretive emphasis has been given to the conditions observed from soil borings. The anticlinal shape of the clayey silt layer generally provides a basis for interpretation of the hydrogeological data.

Hydrogeological data suggest an elevated groundwater flow system in the western portion of the Deterrent Burning Ground, where groundwater levels appear to be up to 7 feet higher than the regional water table. It appears the clayey silt layer impedes vertical groundwater flow, causing the water table in the western portion of the Deterrent Burning Ground to be locally elevated. Near the Existing Landfill and to the southeast, the glaciolacustrine unit appears to grade to a sandy texture allowing the elevated groundwater flow system to recharge into the regional flow system located below the glaciolacustrine unit. As a result, the water table does not appear to be elevated in the vicinity of the Existing Landfill and to the southeast at the Existing Landfill.

Beneath the glaciolacustrine unit, deposits of coarse-grained sand and gravel were encountered. Generally, these deposits were described as poorly graded to well-graded gravels with sand. Based on the absence of silty zones, these materials appear to be composed of glacial outwash and glaciofluvial deposits.

Bedrock was not encountered in borings at the Deterrent Burning Ground or Existing Landfill. However, it is estimated that bedrock is located at an approximate elevation of 650 to 700 feet MSL, with a downward slope to the southeast (see Figure 2-2). This estimate is based on the depth to bedrock encountered in BAAP Production Well Nos. 1 through 5, as well as PBB-89-10, and the logs of several nearby private wells (see Appendix D). The bedrock is likely composed of sandstone with minor amounts of siltstone and shale belonging to the Eau Claire Formation (i.e., Upper Cambrian).

7.3.3 Hydrogeology of Unconsolidated Sediments

This subsection discusses hydrogeologic conditions in the Deterrent Burning Ground and Existing Landfill. Included is a summary discussion of area-wide conditions, followed by more detailed descriptions of each unit including recharge rates, influence of the glaciolacustrine layer on groundwater flow conditions, vertical and horizontal gradients, and interpretation of hydraulic conductivity testing.

Hydrogeologic conditions at the Deterrent Burning Ground and Existing Landfill are largely controlled by the underlying geologic sequence. This sequence includes a low-permeability silty loess at the ground surface underlain by a thick sand and gravel unit comprising a considerable vadose zone. Below this, a discontinuous fine-grained glaciolacustrine layer composed of clayey silt and silty fine sand at the water table restricts the downward movement of recharging groundwater resulting in an elevated water table that is up to 7 feet above the regional water table near the Deterrent Burning Ground. Groundwater flow in this elevated flow system is generally toward the northeast. Below the fine-grained lacustrine layer, coarse-grained sands and gravels comprise the upper portion of the regional aquifer in this area. However, the glaciolacustrine soils appear to act as a semi-confining layer. Horizontal gradients across the regional aquifer are quite low and show variable flow directions in this area. Overall groundwater flow is toward the east-southeast with likely discharge to the Wisconsin River below the WP&L dam. Based on regional conditions throughout the area, it is estimated that the aquifer is approximately 110 feet thick above the bedrock.

A silty loess soil unit at the ground surface (5 to 10 feet thick) occurs in areas undisturbed by landfilling or excavation at the Existing Landfill and Deterrent Burning Ground. This loess unit appears to have a higher permeability near the ground surface where weathering and soil formation processes have acted on the soil materials. This condition is reflected in laboratory hydraulic conductivity testing conducted on soil samples from borings DBM-82-01, DBM-82-02, and ELB-82-04 (Warzyn, 1982a). Test results indicate a permeability of 4×10^{-4} cm/sec in the sample from DBM-82-01 (which contained root holes), and values of $1x10^{-7}$ and $9x10^{-8}$ cm/sec for samples collected from DBM-82-02 and ELB-82-04, respectively (which contained no root holes). As described in Subsection 2.2.3 the loess could limit the amount of precipitation recharging the groundwater to approximately 5 to 7 inches per year.

Below the loess is a relatively thick unsaturated sand and gravel unit (approximately 110 to 130 feet thick) with a higher permeability. Groundwater that percolates through the loess passes through this unit before reaching the water table.

Below the unsaturated sand and gravel unit, a fine silty sand and sandy silt glaciolacustrine unit occurs just above the water table throughout much of the Existing Landfill and Deterrent Burning Ground. As described in Subsection 7.3.2, the upper surface of this glaciolacustrine unit appears to have an anticlinal form with an axis extending roughly north-south between the Deterrent Burning Ground and Existing Landfill. Groundwater flow conditions above the glaciolacustrine unit are complex. It appears that the lower permeability of the glaciolacustrine unit restricts the vertical flow of groundwater. This, along with the anticlinal slope of the glaciolacustrine unit, results in a locally elevated groundwater flow system with a flow direction to the east-northeast below the Deterrent Burning Ground. Table 7-8 summarizes the elevations of groundwater, well screens, and the glaciolacustrine unit at wells in this area. Groundwater levels in wells screened in and above the glaciolacustrine unit at the Deterrent Burning Ground are up to 7 feet higher than would be expected based on the deeper regional flow system. This condition is illustrated by the water level at DBM-89-05 where the elevated water level in the well is approximately 7 feet above the deep regional groundwater elevation.

Water levels beneath the Existing Landfill appear to be elevated 2 feet or less above the regional water table. South and east of the Existing Landfill, water table elevations do not appear to be substantially elevated above regional levels. Southeast of the Existing Landfill, it appears the glaciolacustrine unit has a fine sandy texture and does not sufficiently impede the downward vertical movement of recharging groundwater to support an elevated flow system.

Downward vertical gradients across the glaciolacustrine unit are listed in Table 7-9. The strongest gradient observed in this area is expressed at well nests ELN-82-04B/ELN-82-04C and DBN-89-04A/DBN-89-04B where the downward gradients were calculated to be 0.07 to 0.09 ft/ft. The ELN-82-04A nest is located adjacent to the western boundary of the landfill area. At this location, it appears the

A and B wells are screened above and within the glaciolacustrine unit, while the C well is screened below it. The geologic log for this nest indicates "fine-to-coarse gravel and sand, trace silt" with no distinct glaciolacustrine layer noted (Warzyn, 1982a). However, these soil descriptions are based on drill cuttings from mud rotary drilled holes and may not accurately reflect the true soil conditions encountered. In fact, well purging of ELN-82-04B prior to water quality sampling indicated a poor recharge rate that, along with the relatively strong downward vertical gradient, could reflect low permeability soil conditions associated with the fine glaciolacustrine unit. A similar condition, with stronger vertical gradients encountered in the lower well nest, was also observed at well nest ELN-82-01A, B, and C where a small downward vertical gradient (0.003 ft/ft) was observed between the A and B wells while a larger downward gradient of 0.04 ft/ft was observed between the B and C wells. This well nest also had poor to very poor recovery rates during well purging.

Downward vertical gradients likely decrease below the fine glaciolacustrine layer(s). Well nests DBN-89-02A/DBN-89-02B, and S1122/DBN-82-01B appear to have water table wells with screens extending across the clayey silt unit. This position of the well screens, does not accurately reflect the nature of the vertical gradient across the clayey silt unit at these locations.

Hydraulic conductivity measurements were taken at several existing wells installed at the Deterrent Burning Ground and Existing Landfill. The tests consisted of in situ slug withdrawal tests conducted by ABB-ES. In addition, Warzyn conducted laboratory falling-head permeability tests (Warzyn, 1982a). Results from the ABB-ES tests are summarized in Table 7-10, and the data and analyses for the in situ tests are in Appendix I. Generally, the tests conducted by Warzyn were completed on soil samples collected above the water table, and reflect a somewhat lower hydraulic conductivity estimate than in situ tests conducted by ABB-ES. Hydraulic conductivity tests were not conducted on soils from the fine-grained glaciolacustrine layer described previously. However, based on the physical description of this unit, it is estimated that the fine glaciolacustrine unit could have a hydraulic conductivity on the order of $1x10^{-5}$ to $1x10^{-7}$ cm/sec, depending on the amount of clay and particle size distribution.

In situ tests conducted by ABB-ES focused on the coarse sands and gravels above and below the silty glaciolacustrine unit. As indicated in Table 7-10, hydraulic conductivity of the coarse-grained soil is on the order of $1x10^{-3}$ to $2x10^{-2}$ cm/sec. The higher hydraulic conductivity appears to closely reflect regional aquifer conditions and is in good agreement with the hydraulic conductivity of $5x10^{-2}$ cm/sec calculated from a specific-capacity test completed at Production Well No. 4 by Layne, Inc. (see well data sheet in Appendix D). Given the coarse granular nature of soils encountered below the glaciolacustrine layer, the high hydraulic conductivity range is realistic. Lower hydraulic conductivity values appear to reflect conditions encountered in wells screened partially across the glaciolacustrine unit (i.e., S1153 and ELN-82-04A).

7.3.4 Groundwater Movement

The groundwater flow system at the Deterrent Burning Ground and Existing Landfill is complex; while the general nature of the flow is understood, some details are not well defined. The presence of the fine-grained glaciolacustrine layer with its sloping surface results in an elevated flow system throughout much of the Deterrent Burning Ground area with an elevated groundwater flow direction that differs substantially from the deeper regional flow direction.

Horizontal groundwater flow gradients, directions, and elevations at the Deterrent Burning Ground and Existing Landfill vary considerably between wells installed above and below the fine-grained glaciolacustrine unit. An elevated groundwater contour plan for the area near the Deterrent Burning Ground and Existing Landfill as well as a regional water table contour plan were prepared from water levels collected on December 15, 1991, to assess groundwater flow conditions above and below the lacustrine layer. Generally, only monitoring wells screened above the glaciolacustrine unit in the vicinity of the Deterrent Burning Ground and Existing Landfill were used in generating the elevated groundwater contour plan (Figure 7-15). Wells screened across the water table and located over a broader area were used in generating the regional water table contour plan (Figure 7-16).

Figure 7-15, which illustrates the elevated groundwater contour plan for the Deterrent Burning Ground and Existing Landfill region, depicts an elevated flow system with a northeastern gradient of 0.003 to 0.005 ft/ft across much of the Deterrent Burning Ground. Near the Existing Landfill, the horizontal gradient decreases and the elevated water levels approach the elevation of the regional water table. The horizontal gradient across the elevated flow system beneath the Deterrent Burning Ground is approximately 5 to 10 times greater than the observed regional gradient. Horizontal gradients below the glaciolacustrine deposit are approximately 0.00005 to 0.0008 ft/ft in the regional flow system. Horizontal groundwater gradients are summarized in Table 7-11 for this area. The elevated groundwater contour plan indicates groundwater flow to the east-northeast, whereas the regional groundwater flow system shows how the flow directions change to the south, southeast and southwest in the broader, regional flow system.

Given the geologic and hydrogeologic conditions previously discussed, it appears that in the vicinity of the Deterrent Burning Ground the orientation and fine-grained texture of the glaciolacustrine silt layer elevates groundwater above the regional water table. As groundwater in this elevated flow system flows to the east and northeast, the glaciolacustrine silt layer appears to become thinner and may have a coarser texture. This coarser texture appears to allow the elevated groundwater to seep downward to the regional groundwater flow system. Although thin layers of the glaciolacustrine unit could extend to the east, beyond the BAAP boundary, resulting in an extension of the elevated flow system, it should be noted that the elevated system appears to be a localized, isolated system.

Figure 7-16 illustrates a contour plan for the regional groundwater flow system. This plan was generated using water levels from monitoring wells located throughout the northeast region of BAAP and Formerly Used Defense Sites (FUDS) wells located east of BAAP. This plan was generated using data from wells screened across the water table. As such, it shows how the elevated flow system is superimposed on the regional system. This illustrates the conceptual model of a localized elevated water table underlain by a fine glaciolacustrine unit and then a deeper regional groundwater flow system.

The primary concern regarding deep groundwater flow in this region is whether groundwater from the elevated system, containing site related contaminants (principally SO4), recharges the deep regional flow system and migrates to residential wells located on Badger Road (the Spear well) as well at Wiegand's Bay on Lake Wisconsin. To more precisely assess groundwater elevations in the vicinity of Wiegand's Bay the FUDS program has installed a series of piezometers along Hwy 78 east of BAAP (see well locations designated 91-series shown on Figures 7-16 and 7-17).

Analysis of the groundwater and surface water elevation data in addition to water quality data indicate migration of groundwater containing site related contaminants to Wiegand's Bay is unlikely unless water levels in Lake Wisconsin are allowed (by WP&L, operators of the dam at Prairie du Sac) to drop below the normally maintained level of elevation 774.0 MSL for prolonged periods of time. The analysis, described in detail below, indicates that groundwater within and adjacent to BAAP flows across BAAP. The analysis also indicates that during periods of low groundwater elevation and high surface water elevation Wiegand's Bay has water levels above the surrounding aquifer and therefore may act as a groundwater recharge zone. Conversely, during periods of high groundwater elevation and low surface water elevation Wiegand's Bay has water levels below the surrounding aquifer and therefore may act as a groundwater discharge zone.

Figure 7-16 illustrates groundwater flow directions on December 15, 1992. The figure indicates the deep regional flow system, near the Existing Landfill, flows towards the south-southeast, parallel to the BAAP boundary. However, groundwater flowlines in this area turn more to the south-southwest downgradient from the Existing Landfill, thereby transecting BAAP in the vicinity of the New Landfill. This reflects the movement of groundwater parallel to the Lake Wisconsin reservoir. This conclusion is supported by analytical data from three monitoring wells installed off-post, southeast of the Existing Landfill which show SO4 concentrations within the regional background range.

Figure 7-17 illustrates groundwater flow directions on September 9, 1992. The figure indicates there appears to be a potential for groundwater north of Wiegand's Bay and east of BAAP (more than 1,000 feet east of the BAAP boundary) to be flowing towards the southeast (Wiegand's Bay). However, at a distance of approximately 1,000 feet east of the BAAP boundary groundwater flow appears to be generally towards the south, gradually turning to the southwest further to the south (see Figure 7-17).

Figure 7-17 also indicates the surface water elevation of Wiegand's Bay was 774.23 feet MSL (August 19, 1992) and 775.45 feet MSL (September 30, 1992). Groundwater levels in the COE St Paul District piezometers ranged from 775.19 (piezometer 91-46 at the north end of Wiegand's Bay) to 774.62 (piezometer 91-42 near the southwestern end of Wiegand's Bay) on September 9, 1992. The groundwater and surface water levels are similar. Using the August 19, 1992 surface water level there is the potential for discharge from the aquifer into the reservoir. However, using the September 30, 1992 surface water level there is a potential for recharge from the reservoir into the aquifer. These results suggest a transient condition with a potential for water to flow both out of the aquifer, into the reservoir and out of the reservoir into the aquifer. However, it appears that the portion of the aquifer contributing groundwater to Wiegand's Bay is directly north of Wiegand's Bay extending west to an area approximately 1,000 feet east of the BAAP boundary.

Horizontal gradients calculated between deep monitoring wells screened at similar depths below the water table presented in Table 7-11, indicate a gradient of approximately 0.00005 to 0.0008 ft/ft, with flow to the east-southeast and an approximate potentiometric surface elevation of 780 to 779 feet MSL. The gradient, direction, and elevation are consistent with regional flow conditions. Groundwater levels are somewhat irregular in this area and appear to reflect semi-confined conditions.

Two estimates of the zone-of-influence for Production Well No. 4, located approximately 1,500 to 2,000 feet west of the Deterrent Burning Ground and Existing Landfill, respectively, have been completed (see Appendix H). The zone-of-influence estimate calculated by ABB-ES indicates a 1,200- to 1,600-foot zone-of-influence assuming a flat water table and 300-gpm pumping rate (the average pumping rate from December 1988 to December 1989 was approximately 330 gpm).

To better evaluate the effect of a sloping water table, a capture analysis also was performed for Production Well No. 4 using the CAPTURE Model (McEdwards, 1985). This model incorporates the gradient of the water table surface and plots groundwater flow lines moving to a water supply well, which are illustrated in Figure 7-16. As Figure 7-18 shows, the CAPTURE model indicates an approximate 1,200-foot zone-of-influence although the Existing Landfill and Deterrent Burning Ground, located downgradient of Production Well No. 4, are outside the Production Well No. 4 capture zone, which extends approximately 700 feet downgradient of the production well. It should be noted that the Oleum Plant and Oleum Plant Pond (see Subsection 9.3) are located upgradient of Production Well No. 4. These sites appear to be more closely associated with the capture zone of Production Well No. 4 than the Existing Landfill and Deterrent Burning Ground.

Groundwater velocity analyses were performed separately for the elevated groundwater flow system above the glaciolacustrine silt layer and for the deeper regional groundwater flow system beneath it. Analyses for the elevated flow system indicate a velocity range on the order of 20 to 60 ft/yr, while velocities for the deeper regional flow system are faster, with an estimated velocity range of approximately 50 to 650 ft/yr. This difference is a result of the lower hydraulic conductivity values measured at the water table wells screened in the elevated flow system. The results suggest the elevated flow system may contribute only small quantities of groundwater likely equivalent to the volume of recharge over the area of the elevated flow system to the deeper regional flow system. Calculations and assumptions for these analyses are in Appendix H.

7.3.5 Summary

Geologic and hydrogeologic conditions at the Deterrent Burning Ground and Existing Landfill were analyzed in detail. This analysis indicates a geologic setting that includes a fine silt surficial loess layer overlying a thick sequence of sand and gravel. These soils likely represent reworked tills and glaciofluvial deposits. At a depth of 100 to 170 feet, a fine-grained silty glaciolacustrine unit was encountered in most borings installed in this area. The anticlinal form of the top surface of the lacustrine unit appears to impede groundwater flow and results in an elevated groundwater flow system beneath the Deterrent Burning Ground.

The hydrogeologic analysis indicates subsurface recharge is restricted by the fine-grained loess layer described previously. Water that does infiltrate the loess must pass through a thick vadose zone before recharging the elevated flow system above the silty glaciolacustrine unit beneath the Deterrent Burning Ground. The elevated flow system flows to the northeast, where it appears to recharge the regional water table in the vicinity of the Existing Landfill. The horizontal gradients in the elevated flow system decrease from west to east although they remain an order of magnitude greater than the regional flow gradient. Groundwater flow in the regional water table aquifer is toward the southeast. It appears groundwater from these areas discharges to the Wisconsin River south of the WP&L Dam.

The complex flow pattern between the elevated and regional flow systems has significant implications in the interpretation of groundwater quality. Groundwater flow in the regional system appears to flow more rapidly than in the elevated system. Water infiltrating elevated system migrates slowly northeastward or eastward and downward to mix with the regional system. Where the elevated and regional systems mix, the quality of the groundwater reflects the relative flow rates from the two systems.

7.4 NATURE AND EXTENT OF CONTAMINATION

7.4.1 Introduction

This contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in soil and groundwater at the Deterrent Burning Ground and Existing Landfill. Chemicals that represent site-related contamination were identified based on the evaluations of soil and groundwater sample analytical results as compared to background concentrations; frequency of occurrence and concentrations of each chemical; and the relationship of chemicals to past activities. Because of their proximities, it is both convenient and expedient to group the Deterrent Burning Ground and Existing Landfill together in the following discussion (see Figure 7-1). The contamination assessment is divided into two major segments: (1) contaminant distribution within the Deterrent Burning Ground and Existing Landfill and (2) contaminant fate and transport.

Data collected prior to January 1988 were summarized in the MEP (Tsai et al., 1988). These data contained inconsistencies because the use of differing analytical methods, sampling techniques, and protocols. However, these data are used to augment the description of contaminant nature, distribution, and behavior.

Within this section, results of the field screening techniques (i.e. soil vapor and geophysical surveys) are summarized first. This is followed by results of chemical analyses presented by medium (i.e., subsurface soil and groundwater). Chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). The indicator parameters measured in this program are HARD, ALK, and TDS. Results of soil analyses are generally compared to site-specific and regional background data. Chemical-specific numerical standards and criteria used to evaluate groundwater data are listed in Table 3-3, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WES, and WPALs.

Chemical data tables downloaded from the IRDMIS are contained in Appendix K. Appendix L details specific results of the data quality assessment. This includes (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, a listing of the USATHAMA-certified analytical methods used by the subcontractor laboratories, (2) a summary of the laboratory quality control sample results and impact on associated field sample results, (3) a summary of nontarget, library-searched VOC and SVOC compounds detected in the RI analytical program, and (4) a summary of the USATHAMA-approved laboratory control charts.

At the Deterrent Burning Ground and Existing Landfill, 111TCE, 24DNT, 26DNT, C6H6, NNDPA, NIT, and SO4 were the most prominent chemicals detected. The highest concentrations of the DNTs, C6H6, NNDPA, and SO4 were detected primarily in the subsurface soil of the Deterrent Burning Ground and, with the exception of C6H6, these compounds were also detected in groundwater. 111TCE and NIT were not detected in the subsurface soil samples. The source of 111TCE in groundwater has not been identified, while the source of NIT is likely agricultural fertilizers applied to crop land. Within groundwater, nearly all the contaminants detected were confined to the elevated flow system. The deeper aquifer does not appear contaminated.

7.4.2 Contamination Assessment

The Deterrent Burning Ground and Existing Landfill are related hydrogeologically via a shallow, elevated flow system above a deeper regional flow system as a result of a layer of glaciolacustrine silt. This elevated flow system is not used as a water source although it appears to mix with the deeper aquifer, especially near the northeastern boundary of BAAP. In general, results of analyses are consistent with previous data summarized in the MEP (Tsai et al., 1988). Organic and inorganic chemicals associated with site operations were detected in subsurface soils and groundwater at the Deterrent Burning Ground. Although groundwater quality in the vicinity of the Existing Landfill has also shown some impacts, these are probably related to the Deterrent Burning Ground.

7.4.2.1 Soil Vapor Survey. The passive soil vapor survey was conducted in the Deterrent Burning Ground to assist in the selection of sampling locations. Results were quantified as ion counts which reflect the relative flux of the contaminants being measured rather than actual concentrations. As such, a high flux may reflect a permeable flow path rather than close proximity to source materials. The survey included the 2-acre man-made depression (approximately 20 feet deep) and the older, filled area to the west. The primary target compounds for the soil vapor survey were halogenated and fuel-related VOCs. The results are presented in Appendix B, Figures B-10 through B-12. Figure B-10 illustrates the relative flux for simple aromatics; Figure B-11 shows the relative flux for alkanes; and Figure B-12 presents the relative flux for TRCLE.

Ion counts of simple aromatics and alkanes were reported at 10 times background levels in the northwestern portion of the depressed area. This area is believed to be a discrete burning area. Ion counts of TRCLE were 500 to 1,000 times those of background levels in the northwestern area of the older filled area. This may indicate another older burning area. A soil vapor survey was not conducted at the Existing Landfill.

7.4.2.2 Geophysical Survey. A geophysical survey was conducted to assist in the selection of sampling locations. Surface geophysical techniques applied at the

Deterrent Burning Ground were TC and GPR surveys. Surface geophysics were not performed by ABB-ES at the Existing Landfill. The approach to the TC and GPR surveys is described in Subsection 7.2.2; the detailed results are in Appendix C, Figures C-8 through C-11. The geophysical surveys were confined to the 2-acre man-made depression. The TC survey indicated the presence of two "high-conductivity" zones. The most prominent zone is located in the west-central portion of the Deterrent Burning Ground area, while a second, less pronounced zone is located in the northeastern portion of the Deterrent Burning Ground.

The GPR survey indicated four anomalous zones, two of which were characterized by a lack of reflections, while the other two were characterized by shallow, moderate-to-strong reflections common in waste disposal areas. It is likely the high-conductivity zones identified in the TC survey reflect the presence of electrically conductive subsurface materials generated by past disposal practices at this site. Anomalies identified in the GPR traverses may possibly reflect fill conditions related to past site activities.

7.4.2.3 Subsurface Soil. Using information obtained from aerial photographs and the passive soil gas survey, three soil borings were placed in the Deterrent Burning Ground corresponding to locations in which the passive soil vapor survey indicated high VOC fluxes. These locations are designated DBB-91-01, -02, and -03 (see Figure 7-1) and a total of 44 samples were collected from these borings for chemical analyses. Subsurface soil samples were collected from the Deterrent Burning Ground borings to identify possible sources of groundwater contamination, characterize the probable extent of the source areas, and evaluate the extent of chemical migration. Table 7-12 summarizes the chemical subsurface soil data with detectable results. It should be noted that this table only lists analytes with detectable concentrations in one or more of the samples from this site. Appendix K lists all analytical results and Table 7-3 summarizes all analyses performed.

Generally, previous studies indicated that high concentrations of DNTs (0.8 to 33,000 μg/g), diphenylamines (16 to 1,400 μg/g), and phthalates (2 to 7,400 μg/g) are probably localized in the three pits used for burning deterrent (Tsai et al., 1988). Soil samples collected within the burning ground depression, but outside the pits, showed little contamination (DBB-82-01 and DBB-82-03), indicating that the contamination did not migrate horizontally, but rather vertically.

7.4.2.3.1 Volatile Organic Compounds

The VOCs detected in soil borings DBB-91-01, DBB-91-02, and DBB-91-03 include C6H6, MEC6H5, 13DMB, TXYLEN, and CH2CL2. Analytical results are presented in Table 7-12. The VOC discussion summarizes the conditions in all three borings jointly. CH2CL2 was also detected in trip and method blanks and its presence is attributed to laboratory contamination (see Appendix L).

C6H6 was the principal VOC detected in the borings at the Deterrent Burning Ground and the most frequent detects and highest concentrations were encountered in boring DBB-91-01 where C6H6 was detected 2 to 25 feet bgs with a maximum concentration of 76.6 μg/g at 25 feet bgs (see Figure 7-19). In DBB-92-02, C6H6 was only detected in the 4-foot and 6-foot bgs samples with a maximum concentration of 1.56 μg/g in the 4-foot sample. In DBB-91-03, C6H6 was detected in the 4-foot and 8-foot bgs samples with a maximum concentration of 0.002 μg/g in the 8-foot bgs sample. Detects in DBB-91-03 are near the certified reporting limit and are considered estimated values. C6H6 was not detected in any of the borings near the water table (110 feet bgs).

MEC6H6 and 13DMB were also detected in the upper portions of boring DBB-91-01 with maximum concentrations of 2.07 and 0.584 μg/g, respectively. Neither of these compounds was detected in borings DBB-91-02 nor DBB-91-03. TXYLEN was detected in DBB-91-03 in two samples with very low concentrations (0.002 μg/g maximum) at depths of 12 to 14 feet bgs. The presence of these relatively low concentrations of VOCs at depths well above the water table, which is approximately 110 feet bgs in this area, suggests a low potential for VOC impact on groundwater quality in this area.

It is not clear from the MEP whether C6H6, XYLEN, ETC6H5, and MEC6H5 were not detected or not analyzed in many of the previous studies (Tsai et al., 1988). However, Piercy detected C6H6 (11 to 51 μg/g) when high concentrations (6,000 to 7,000 μg/g) of dibutylphthalate were detected in soil borings (Piercy, 1977). This supports the possibility that the presence of C6H6 and other fuel-related compounds could be related to the SVOCs, possibly indicating incomplete combustion of deterrents and fuel.

7.4.2.3.2 Semivolatile Organic Compounds

The predominant SVOCs detected at the Deterrent Burning Ground include 24DNT, 26DNT, NNDPA, and DNBP followed by DEP and trinitrotoluene (3NT) with minor amounts of B2EHP, FANT, PYR, and PHANTR. The analytical results are summarized on Table 7-12, and the results from each boring are discussed separately below. Overall, the results support the understanding that these locations were used for burning deterrent. Once again, DBB-91-01 had the highest contaminant concentrations of the three borings.

At DBB-91-01, 24DNT, 26DNT, NNDPA, and DNBP were detected in the shallow subsurface soils at depths of 2 to 25 feet bgs at concentrations up to 37,000 μg/g (24DNT at 8 feet bgs), 970 μg/g (26DNT at 15 feet bgs), 5,200 μg/g (NNDPA at 25 feet bgs) and greater than 62 μg/g (DNBP at 10, 15, and 20 feet bgs). Distribution of DNTs and NNDPA in subsurface soils from the three borings are presented in Figure 7-20 and Figure 7-21, respectively. The concentrations of these compounds decrease substantially at depths greater than 25 feet bgs. These results correlate well with field observations recorded in the boring log for DBB-91-01 which indicates soils were discolored with yellow-green to black staining and a noticeable "chemical odor" at depths to 25 feet bgs. 3NT (up to 14.3 μg/g at 25 feet bgs) and DEP (up to 25.9 μg/g at 15 feet bgs) were also detected in the soil samples less than 25 feet bgs in boring DBB-91-01.

At depths greater than 25 feet bgs, the concentration of the compounds listed above decreased substantially, particularly for 24DNT and 26DNT. Soil samples indicated only trace level contamination (less than 1 μg/g) at depths greater than 72 feet bgs and no SVOCs were detected in samples collected from the water table at 117 feet bgs. Several other VOCs were detected in boring DBB-91-01 including B2EHP and n-nitrosodimethylamine (NNDMEA). However, their frequency (only one or two detects) and concentration (maximum 1.46 μg/g) indicate they are not major contaminants at this location.

At DBB-91-02, 24DNT, 26DNT, NNDPA, and DNBP were again the predominant contaminants detected. However, at this boring their concentration and frequency of detection were lower. Shallow subsurface soils at depths of 4 to 8 feet bgs had concentrations up to 2,500 μg/g (24DNT at

6 feet bgs), 230 μg/g (26DNT at 6 feet bgs), 460 μg/g (NNDPA at 6 feet bgs), and greater than 6.2 μg/g (DNBP at 4, 6, and 8 feet bgs). The concentrations of these compounds decrease substantially at depths greater than 10 feet bgs. It should be noted that the field observations from this boring did not indicate discoloration or unusual odors.

At depths greater than 8 feet bgs these compounds were generally not detected although the sample from 27 feet bgs did indicate trace level concentrations (all below 3.65 μg/g). With the exception of a trace concentration of NNDPA (0.098 μg/g), no SVOCs were detected in the soil sample collected at the water table.

At DBB-91-03, 24DNT, 26DNT, NNDPA, and DNBP were again the predominant contaminants detected. At this boring their concentration and frequency of detection were intermediate between that observed at DBB-91-01 and DBB-91-02. Shallow subsurface soils at depths of 4 to 22 feet bgs had concentrations up to 6,000 μg/g (24DNT at 14 feet bgs), 1,400 μg/g (26DNT at 8 feet bgs), 820 μg/g (NNDPA at 14 feet bgs), and greater than 6.2 μg/g (DNBP at 12, 14, and 16 feet bgs). B2EHP was also detected in all but one of the samples less than 22 feet bgs although the concentrations were quite low (less than 5.79 μg/g). Except for a trace detect of DNBP (1.5 μg/g) at 42 feet bgs, there were no other detections for these compounds in this boring, including at the water table.

Several other SVOCs were sporadically detected at trace concentrations in DBB-91-03 at depths less than 14 feet bgs including 2MNAP, FANT, PHANTR, and PYR. These compounds were only detected in one sample each and the maximum concentration was 0.183 μg/g. As such, they are not considered major contaminants at this site.

The three borings made during the RI, detected SVOCs that reflect the historic burning of deterrent in the pits at the Deterrent Burning Ground. The predominant SVOCs associated with these pits are concentrated in the upper 20 to 25 feet of soil. Boring logs from DBB-91-01 and DBB-91-03 indicate a higher silt content at this depth. It appears this geologic condition could be retarding the downward migration of these contaminants.

7.4.2.3.3 Inorganics (Metals and Anions)

Soil samples from the Deterrent Burning Ground were analyzed for total metals. Analytical results with detects are presented on Table 7-12. The analyses were performed for Priority Pollutant metals and included AG, AS, BE, CD, CR, CU, PB, HG, NI, SB, SE, TL, and ZN. These analyses have indicated concentrations below certified reporting limits or within background conditions for BAAP. However, two exceptions were noted. The first is an analysis for PB at a depth of 6 feet bgs in boring DBB-91-01 where the measured concentration was 20.2 μg/g, which is only slightly above the site-specific background level of less than 7.5 to 15.7 μg/g. The second exception was an analysis for ZN at a depth of 102 feet bgs in boring DBB-91-03, where the measured concentration was 106 μg/g, which is above the site-specific background level of 52 to 81 μg/g. These isolated sample results are not considered significant.

At the Deterrent Burning Ground, soil samples were collected at various depths from the three soil borings and analyzed for CD, CR, HG, and PB using the TCLP analysis. The tests were conducted to evaluate leaching and migratory potential of CD, CR, HG, and PB in subsurface soil at the three borings and to determine if the soil at these locations would be characterized as a hazardous waste because of their toxicity characteristic. A summary of the TCLP metals data is presented in Table 7-13. AT DBB-91-01, only HG was detected at 2, 6, and 8 feet bgs at extract concentrations below 1 μg/ℓ. At DBB-91-02, CR was detected at 72 feet at an extract concentration slightly above 20 μg/ℓ, and again HG was detected at 14, 27, 42, 62, and 72 feet bgs at extract concentrations below 1 μg/ℓ. At DBB-91-03, CD was detected in the extract at approximately 8 μg/ℓ and at 27 feet bgs, CR was detected at approximately 36 μg/ℓ in the extract from the 4-foot bgs sample. PB was not detected above the certified reporting limit in any of the samples collected at all three borings. None of the concentrations of the metals detected exceeded the TCLP regulatory levels.

NIT and SO4 were analyzed for in all soil samples from the Deterrent Burning Ground borings. NIT results were somewhat above the maximum site-specific background level of 4 μg/g in soil samples from 2 to 10 feet bgs in DBB-91-01, at 14 feet bgs in DBB-91-02, and at 8 to 18 feet bgs in DBB-91-03. However, the maximum NIT measured concentration was

18.7 $\mu g/g$, indicating no major NIT contaminant source in subsurface soils at the Deterrent Burning Ground.

SO4 results were generally below certified reporting limits DBB-91-01 and 02, although some SO4 was detected in samples collected near the water table. At DBB-91-03, SO4 concentrations of 29.9 to 240 $\mu g/g$ were detected in samples from 20 to 122 ft bgs. SO4 was not detected in subsurface background soils above the certified reporting limit of 5 $\mu g/g$. No known source is attributable to these concentrations. It should be noted that substantial SO4 concentrations (up to 630,000 $\mu g/\ell$) have been detected in groundwater samples from monitoring wells in this area.

7.4.2.3.4 Interpretation of Subsurface Soil Data

The most predominant VOC detected in subsurface soils at the Deterrent Burning Ground is C6H6. C6H6 is known to have been used in DNT extraction processes at the facility and these two compounds often coexist in the subsurface soils beneath the Deterrent Burning Ground. C6H6 may also be present as a component of fuels reportedly used to initiate combustion of deterrents at the Deterrent Burning Ground. This is supported by the detection of other fuel-related VOCs such as 13DMB, MEC6H6, and TXYLEN in subsurface soil samples. 111TCE, and closely related 1,1,2-trichloroethane (112TCE), which are found in groundwater samples from this area were not detected in the subsurface soil samples.

Samples from all three borings contain SVOCs that reflect the historic burning of deterrent in the pits at the Deterrent Burning Ground. The predominant SVOC contaminants detected were 24DNT, 26DNT, NNDPA, and DNBP.

Generally, the highest concentrations of VOCs and SVOCs were detected in the upper 20 to 25 feet of soil. Boring logs from the three borings indicate a higher silt content above this depth. Fine-grained silt layers in the subsurface could retard the downward movement of contaminants, resulting in lower concentrations of SVOCs below this zone. This agrees with the laboratory analytical data. However, the silt layers do not appear to present a complete barrier to downward migration of chemicals, as indicated by the presence of low concentrations of 24DNT and DNBP below 40 feet.

Concentrations of inorganic analytes, including metals and anions, were within background ranges, with the exception of SO4. The presence of high levels of SO4 in boring DBB-91-03 at depths of 20 to 122 feet bgs could be related to the high SO4 concentrations observed in groundwater samples. However, the lack of SO4 in near-surface soils suggests that the SO4 has either been leached from the soil, or did not originate at this location. The SO4 could have been transported to this area from the filled portion of the Deterrent Burning Ground to the west of the current pit locations. This hypothesis is supported by the higher concentrations and greater vertical distribution of SO4 in boring DBB-91-03, which was drilled further to the west than borings DBB-91-01 and DBB-91-02.

7.4.2.4 Groundwater. As described in Subsection 7.2.7, existing and recently installed wells at the Deterrent Burning Ground and Existing Landfill were sampled and analyzed in two rounds by ABB-ES during the RI. For an analyte to be considered reflective of actual site conditions, it must have been detected in both rounds of sampling at a given well. Table 7-14 summarizes the groundwater data with detectable results. This table only lists analytes with detectable concentrations in one or more of the samples from this site. Appendix K lists all analytical results and Table 7-7 summarizes all analyses performed.

Most site-related contaminants detected in groundwater occurred in the elevated flow system and are primarily limited to 111TCE, 26DNT, NNDPA, SO4, and NIT.

As described in Subsection 7.3.3, groundwater in the elevated flow system beneath the Deterrent Burning Ground flows east-northeast toward the northeastern BAAP facility boundary. Data indicate that releases of site-related chemicals from the Deterrent Burning Ground affect this elevated groundwater zone. Impact on the deeper regional aquifer, which flows southeast below the glaciolacustrine sediments, is minimal. The compound most clearly showing the characteristics of a groundwater plume at this site is SO4, detected in a series of wells screened in the elevated flow system from the Deterrent Burning Ground to the northeast BAAP facility boundary. 111TCE occurs in the same area with a less extensive plume. 26DNT and NNDPA also occur sporadically in this area but appear to be confined largely to the area of the Deterrent Burning Ground.

NIT concentrations in excess of the WPAL occur in many of the wells although the levels do not exceed the WES. Although there are generally no major impacts with metals in this area, it should be noted that CR was detected in nearly all wells in

Round One, but was detected very infrequently in Round Two. The CR detected in Round One is attributed to laboratory bias (see Subsection 7.4.2.4.5). B2EHP was detected at low levels and is attributed to laboratory and/or sampling artifacts (see Appendix L).

7.4.2.4.1 Volatile Organic Compounds

Prior sampling and analysis of monitoring wells located in the Deterrent Burning Ground and Existing Landfill resulted in only sporadic detection of most organic contaminants. Analytical results for VOCs detected in groundwater are summarized in Table 7-14; their distribution for Rounds One and Two are shown in Figure 7-22.

111TCE and the closely related compound 112TCE are the only VOCs detected consistently, both historically and in Rounds One and Two. However, the WPAL for 111TCE (40 µg/l) was not exceeded in any groundwater samples collected. The new wells, DBN-89-04A, ELM-89-09, and ELM-89-01, along with older wells DBM-82-02, ELN-82-03B, and S1134 are screened in the elevated flow system and contain 111TCE and/or 112TCE (see Figure 7-22). Samples from the deeper aquifer contained no 111TCE. The 111TCE distribution is similar to, although not as extensive as, that of SO4.

112TCE was detected in wells ELM-89-09, ELN-82-03B and S1134 at concentrations ranging from 0.365 to 2.31 µg/ℓ. 112TCE was also detected outside the plume area in well ELM-89-07 during Round One (0.462 µg/ℓ). However, this result was not confirmed during Round Two.

Several other VOCs (e.g., 13DMB, trimethylbenzenes (TRIMBZ), TRCLE, phenol (PHENOL), MEC6H5 also appear with no consistent spatial or temporal pattern. Most of these VOCs were detected only in Round One. In all cases the detected concentrations were at either very low or trace levels. Because of their sporadic distribution, the low to trace concentrations at which these compounds were detected, and their detection in only one round at a given well, these data are not considered indicative of a defined plume at the Deterrent Burning Ground or Existing Landfill.

7.4.2.4.2 Semivolatile Organic Compounds and Nitrosamines

Results of SVOC and NAM analyses are summarized in Table 7-14, and the distribution of 26DNT and NNDPA is also shown in Figure 7-22. The most common SVOC detected in both the elevated flow system and the deeper regional flow system was the phthalate ester B2EHP, which was detected sporadically and without a discernible spatial or temporal pattern. Because of its sporadic detection, presence in the method blanks and possible correlation with PVC cuttings from well installations, B2EHP is not considered a site contaminant.

NNDPA and 26DNT were detected in monitoring wells screened in the elevated flow system near the Deterrent Burning Ground. NNDPA was detected in Rounds One and Two in DBM-82-01 (16.7 and 14.5 μg/ℓ) and in Round Two only in DBM-82-02 (1.02 μg/ℓ). The full extent of the NNDPA plume cannot be evaluated as wells at the Existing Landfill were not tested for NAM which includes NNDPA. 26DNT was also in well DBM-82-01 during both Rounds One and Two (2.17 and 1.29 μg/ℓ). Both NNDPA and 26DNT were detected in significant concentrations in the subsurface soils in borings DBB-91-01, DBB-91-02, and DBB-91-03. Their presence in groundwater samples from wells downgradient of the Deterrent Burning Ground likely reflects the leaching of contaminants from the unsaturated subsurface soils into groundwater.

7.4.2.4.3 Inorganics (Metals and Anions)

The primary metal of interest regularly detected above WPAL in groundwater at the Deterrent Burning Ground and the Existing Landfill is CR. Other metals occasionally detected at concentrations above regulatory standards include CD, PB, HG, and SE. All inorganics detected in groundwater at the Deterrent Burning Ground and Existing Landfill are summarized in Table 7-14. The data indicate there is no consistent distribution of any metal that would indicate a source area. Figure 7-23 presents detected concentrations of metals in groundwater at the Deterrent Burning Ground and Existing Landfill.

During Round One, CR was detected in 36 of 39 groundwater samples at concentrations ranging from 4.98 to 48.5 μg/ℓ. Of these, 35 samples exceeded the WPAL of 5 μg/ℓ. However, during Round Two only 2 samples had detectable concentrations of CR. One of these samples was from well ELN-89-02A (140 $\mu g/\ell$) which is not functioning properly. Evidence of grout contamination within the well casing includes visual observations of grout during sampling and high pH (9.8). The other Round Two CR detect occurred in well ELN-82-04C (5.14 $\mu g/\ell$). The CR results are attributed to laboratory bias (see Subsection 7.4.2.4.5). As discussed in Section 3, the WDNR is currently considering a revision to the WPAL and WES for CR.

CD, HG, PB, and SE were detected sporadically in a limited number of wells during both sample rounds. CD was detected at 3.23 $\mu g/\ell$ (above the WPAL of 1 $\mu g/\ell$) in Round One at DBN-89-02A. HG was detected at 4.25 $\mu g/\ell$ (above the WES of 2 $\mu g/\ell$) in Round Two at ELM-89-05. PB was detected in four wells, ELN-82-02B, ELN-82-02C, and ELM-89-05 during Round One and ELM-89-05 during Round Two along the BAAP facility boundary with a concentration range of 5.94 to 8.61 $\mu g/\ell$ (above the WPAL of 5 $\mu g/\ell$). SE was detected in Round One at 4.03 $\mu g/\ell$ at ELN-82-03B and at 5.01 $\mu g/\ell$ at S1134 (these are above the WPAL of 1 $\mu g/\ell$). These sporadic results do not suggest a consistent spatial or temporal pattern and as such the metals distribution is not considered indicative of a site-related contaminant plume.

Anions of interest detected at concentrations above the regulatory WPAL at the Deterrent Burning Ground and Existing Landfill include SO4 and NIT. SO4 distribution shows the clearest plume definition of all analytes at these sites. NIT concentrations above the WPAL are detected across much of the site.

SO4 was detected in a well-defined plume with concentrations above the WES of 250,000 $\mu g/\ell$ in a series of monitoring wells screened in the elevated flow system. This plume extends from the Deterrent Burning Ground to the east, to the BAAP facility boundary as illustrated in Figure 7-24. Monitoring wells adjacent to, but outside, the plume (as portrayed in Figure 7-24) have lower SO4 concentrations ranging upward to 69,000 $\mu g/\ell$. Other wells in the area of the Deterrent Burning Ground and Existing Landfill have SO4 concentrations ranging from 9,500 to 52,000 $\mu g/\ell$. SO4 concentrations in background wells ranged upward to 41,000 $\mu g/\ell$. These results are consistent with earlier sample analyses from this area.

The SO4 plume appears to begin near the northern end of the Deterrent Burning Ground where the highest concentration of SO4 was detected

(630,000 $\mu g/\ell$ in well DBM-82-02). The plume extends to the east northeast along the southern boundary of the Existing Landfill to the BAAP facility boundary. At the BAAP facility boundary, the SO4 concentration of 190,000 to 200,000 $\mu g/\ell$ measured at ELM-91-10 is below the WES but above the WPAL. These SO4 concentrations are below the 310,000 to 630,000 $\mu g/\ell$ concentrations detected along the southern boundary of the Existing Landfill. The lower concentrations measured at ELM-91-10 may reflect the mixing and dispersion of the elevated groundwater flow system into the deep regional flow system.

Additional monitoring wells could not be installed east of the BAAP facility, as right-of-entry agreements could not be reached with the adjacent land owner. However, the COE St Paul District have installed a series of three monitoring wells immediately east of BAAP on the Spear property. Although these wells were installed to assess a potential off-post waste site previously utilized by BAAP, their location (see Figure 7-16) downgradient and east of the Existing Landfill makes them useful for evaluating the potential extension of the SO4 plume east of BAAP. Analytical results from groundwater samples collected from these wells have shown SO4 concentrations (18,000 to 33,500 $\mu g/\ell$) within the regional background concentrations. This data indicates the SO4 plume has not measurably impacted the ground water quality in the vicinity of these wells.

Monitoring wells exhibiting SO4 concentrations over 250,000 $\mu g/\ell$ are screened in the elevated flow system. Well ELN-82-03C is the only well screened in the deep flow system within the "footprint" of the SO4 plume. This well has SO4 concentrations of 57,000 to 61,000 $\mu g/\ell$ which are slightly above the background level, but below the WPAL. These results could reflect the leaching of SO4 from the elevated system into the regional flow system.

Wells north (DBN-89-04A) and south (S1122) of the Deterrent Burning Ground did not exhibit high SO4 levels. West of the Deterrent Burning Ground, the nearest well is Production Well No. 4 located 1,400 feet to the northwest and screened in the deeper regional flow system. Production Well No. 4 has SO4 concentrations ranging from 41,000 to 97,000 $\mu g/\ell$.

Significant concentrations of SO4 were detected in subsurface soil samples collected from boring DBB-91-02 (75.7 $\mu g/g$) at the water table. At

DBB-91-03, SO4 was detected at concentrations ranging from 240 to 29.9 μg/g in unsaturated soils as well as in saturated soils at the water table (54.3 μg/g).

NIT concentrations above the WPAL of 2,000 μg/ℓ were detected at 18 wells during Round One and at 10 wells during Round Two at Deterrent Burning Ground and Existing Landfill wells. However, the WES of 10,000 μg/ℓ was only exceeded at one well (DBM-82-01, 16,000 μg/ℓ in Round Two). The NIT concentration distribution is illustrated in Figure 7-25. There is no overall spatial or temporal pattern that suggests a NIT plume related to activities at these sites. NIT concentrations in the elevated flow system are generally equal to or lower than the concentrations in the deeper regional flow system. As with other sites at BAAP, the NIT concentrations detected during Round One are generally somewhat higher than the concentrations detected during Round Two.

7.4.2.4.4 pH and Specific Conductance

During ABB-ES' groundwater sampling program (Rounds One and Two), pH and specific conductance were measured during well sampling. The data were recorded on a Field Data Record sheet for each well (see Appendix F) and are included on Table 7-14. The pH and specific conductance of the wells were evaluated to determine whether fluctuations or significant increases or decreases occurred with either parameter. Variations can provide an indication of trends in the analytical data for anions and cations.

The pH at the Deterrent Burning Ground remained stable and within the background range measured for BAAP (i.e., 6.5 to 8.4) throughout the two sampling rounds (see Table 7-14). The specific conductance also remained consistent and within background (i.e., 244 to 570 μmhos per centimeter [μmhos/cm]), with the exception of DBM-82-02 (1,304 μmhos/cm), which may reflect high SO4 concentrations at this well.

The pH at the Existing Landfill also remained stable throughout the two sampling rounds, with the exception of ELN-89-02A (9.8, Round Two). No analytical results are presented for Round One (see Table 7-14) as the well was dry. The Round Two Field Data Record for this well indicated that the groundwater sample contained fine white suspended solids, which may be grout contamination. Grout is used to backfill around the monitoring wells and contains calcium hydroxide, which would cause an increase in pH in the groundwater. This explanation would also account for the high CA concentration (470,000 $\mu g/\ell$) detected in the Round Two sample.

As stated, the pH for most of the Existing Landfill wells remained fairly stable and within background. However, the specific conductance was significantly higher (i.e., greater than 1,000 μmhos/cm) than background in a number of wells (see Table 7-14). Most of the wells where a high specific conductance was consistently measured during both sampling rounds are wells with high SO4 concentrations.

7.4.2.4.5 Interpretation of Groundwater Data

Figure 7-22 illustrates the area in which 111TCE and NNDPA were found in groundwater. Data from the wells in this area indicate the presence of 111TCE being transported in the elevated flow system from the Deterrent Burning Ground toward the northeast BAAP facility boundary (see Figures 7-15 and 7-22). The distribution of 111TCE indicates it may originate at the Deterrent Burning Ground. However, 111TCE was not detected in the borings at the Deterrent Burning Ground. NNDPA was detected in all three borings at the Deterrent Burning Ground although the highest concentration (up to 5,200 $\mu g/g$) were all detected in the upper 8 to 25 feet of these soil borings. At DBB-91-02, NNDPA was detected at the water table although the concentration was only at a trace level (0.098 $\mu g/g$).

Soil boring data indicated high levels of 24DNT and 26DNT in the upper 8 to 25 feet of the soil column beneath the Deterrent Burning Pits. The literature value for the K_{oc} for 24DNT is low, predicting a higher concentration of DNTs in groundwater than observed. DNTs appear to be sorbed strongly to soil, particularly those soil zones with higher silt contents, and are not being transported in the groundwater as far as 111TCE. The effect of the polarity of the DNTs appears to be more important than the adsorption on organic carbon.

High concentrations of SO4 in groundwater (Figure 7-24) could be a result of disposal of wastes such as neutralization sludge associated with sulfuric acid (used in the nitration process) or ash from the on-site power plants. Visual interpretation of aerial photographs from 1955 and 1962 indicate the possible placement of boiler ash in the western and northern portions of the Deterrent Burning Ground and in the Existing Landfill. The high concentrations of SO4 in groundwater begin at DBM-82-02, located on the northern edge of the Deterrent Burning Ground. High concentrations of SO4 in this area are supported by the presence of SO4 in subsurface soil borings from this area. Based on subsurface soil chemical data, groundwater chemical data, and groundwater flow direction in the elevated flow system, the Deterrent Burning Ground appears to be the source of SO4 detected in groundwater. However, it is possible that the Existing Landfill is contributing a small percentage of the SO4 observed in groundwater.

As described in Subsection 7.3, the geologic conditions and vertical hydraulic gradient data suggest that the fine-grained lacustrine soils, which are responsible for the presence of the elevated flow system at the Deterrent Burning Ground, become more discontinuous with a coarser texture to the east. These changes appear to allow the elevated flow system to dissipate in this area (i.e., leakage or downward flow to recharge the deeper regional flow system). At ELM-91-10, it appears the mixing of the elevated flow system with the regional flow system might result in the lower SO4 concentrations in this area. This could explain the substantially lower SO4 concentrations detected at ELM-91-10 relative to S1134 and ELN-82-03A. In summary, water from the elevated flow system containing higher SO4 concentrations migrating to and mixing with water from the regional system may be diluted as the regional groundwater, which contains lower SO4 concentrations, flows through this area.

Metals concentrations in groundwater samples were within background concentrations, with the exception of CR. CR was detected in the majority of wells in Round One, but appeared in only two wells in Round Two. Potential sources of laboratory contamination and error were investigated to explain these CR data. No definitive sources of laboratory contamination or error were found. In addition, field records were checked and field personnel questioned; standard field sampling practices were followed during both rounds of groundwater sampling. Although definitive conclusions about the source of the CR bias have not been reached, the following observations can be made: (1) CR was present in method blank samples during Round One but not Round Two, (2) standard matrix spike recoveries for CR were higher during Round One (Appendix L), (3) CR was detected in laboratory analyses from monitoring well and production/residential well samples in Round One but not in Round Two, and (4) the same lot of acid preservative used in Round One was also used in Round Two. Given these observations, it appears the CR detected in Round One groundwater samples is the result of a laboratory bias.

In summary, the most prevalent chemicals detected in the Deterrent Burning Ground groundwater include 26DNT, NNDPA, 111TCE, NIT, and SO4. The chemicals have higher concentrations in the elevated flow system, with little impact in the deeper regional aquifer.

The SO4 plume (exceeding WESs) in groundwater can be attributed to the probable source area at the Deterrent Burning Ground. Although the 111TCE plume was partially defined based on analytical data (see Figure 7-22), a source area was not identified. Finally, the presence of NIT concentrations above the WPAL could be due to the current and past use of nitrate fertilizers in the agricultural areas.

Review of the BAAP quarterly groundwater data through September 1992 from the Deterrent Burning Ground and Existing Landfill identify the same principal contaminants as the RI data. SO4 is the principal contaminant detected in both the BAAP quarterly data and the RI data exceeding the WPAL and WES at selected monitoring wells. The SO4 data shows a clear contaminant plume. NIT was also found at concentrations above the WES and WPAL in the BAAP quarterly data. However, the high NIT concentrations occur both up and downgradient of the site and, as such cannot be directly attributed to the Deterrent Burning Ground as a source. The BAAP quarterly data shows some variability in CR concentrations with a high spike in 1989 to 1990 which has gradually decreased over time. This condition is similar to the CR detected during the RI. The BAAP quarterly data also indicates that specific conductance and hardness are increasing in selected wells.

Monitoring well ELN-89-02A has shown notable results in the BAAP quarterly data. This includes high concentrations of CR (up to 1,400 $\mu g/\ell$) and MEC6H5 (up to 1,700 $\mu g/\ell$). As previously discussed in this RI, this monitoring well appears to be contaminated with grout and is not functioning properly. The BAAP data also shows concentrations of CD and CR in most wells in this area exceeding the WES during the July 1989 and occasionally the September 1989 sample rounds.

26DNT was detected in both Rounds One and Two of the RI in monitoring well DBM-82-01, was detected in the BAAP quarterly sampling round data in September 1990 in monitoring well DBN-82-01B (8.8 $\mu g/\ell$). The related SVOC, 24DNT was also detected in the BAAP quarterly sampling round data in September 1992 in monitoring well DBM-82-02 (0.23 $\mu g/\ell$). The DNT detects in the BAAP quarterly data occurred in only 1 of 15 sample rounds.

It should be noted that selected compounds detected during the two rounds of RI sampling were not detected during the BAAP quarterly sampling. 111TCE and 112TCE were generally not detected in the BAAP quarterly data but were detected in the RI data. These compounds were generally detected at concentrations below the detection limit of the BAAP quarterly data.

7.4.2.5 Environmental Fate of Contaminants. The chemical and physical behavior of major contaminants at the Deterrent Burning Ground/Existing Landfill are described in terms of how they affect the environmental fate, and especially migration potential, of the contaminants. Table 7-15 lists the organic chemicals considered major contaminants at the Deterrent Burning Ground/Existing Landfill and summarizes their chemical and physical properties. Table 7-16 tabulates results of a simple contaminant migration model for the major organic chemicals. The depth to groundwater is relatively great at the Deterrent Burning Ground/Existing Landfill (more than 100 feet) and the potential exists for significant volatilization in the soil column for many compounds.

Contaminants detected in groundwater at the Deterrent Burning Ground include NNDPA, 26DNT, 111TCE, SO4, and NIT. NNDPA and 26DNT were only detected in monitoring wells immediately adjacent to the Deterrent Burning Ground. The 26DNT concentration is above the WPAL and WES. 111TCE was found in groundwater at concentrations less than the WPAL; its behavior and environmental fate are similar to that of TRCLE except that 111TCE does not follow the same degradation pattern as TRCLE. NIT and SO4 areas are somewhat different and reflect the fact that some of their sources may be different. Because multiple and ill-defined sources are involved, the behavior and migration of apparent plumes or areas of contaminated groundwater are not easily predicted. Further, the extent of the plumes suggests they have been in place for some time.

Behavior of contaminants at the Deterrent Burning Ground is expected to be the same as that described for the Propellant Burning Ground (Section 6.0). The major difference between the two sites is the presence of the elevated flow system, as described in Subsection 7.3.

7.4.2.6 Summary of Contamination. Organic and inorganic chemicals related to processes used at BAAP have been found in subsurface soil and groundwater at the Deterrent Burning Ground.

At the Deterrent Burning Ground, 111TCE was detected in the elevated groundwater flow system extending to the southern boundary of the Existing Landfill; however, no source was identified, and the concentration of 111TCE was below the WPAL. As at the Propellant Burning Ground, NNDPA and DNTs were detected in soils and in a limited area of the elevated groundwater flow system; however, results of the DNT analyses prevent a clear interpretation of the extent of DNT migration. NNDPA was analyzed in a limited number of wells at the Existing Landfill wells (ELM-91-10, ELN-91-07A, and ELN-91-07B). NNDPA was not detected in these wells which are located along the northeast BAAP boundary.

No metal concentrations consistently above background were detected in the soil or groundwater samples at the Deterrent Burning Ground or Existing Landfill.

Groundwater beneath the Deterrent Burning Ground also contains SO4 concentrations above background, which forms a well-defined plume. This area of higher SO4 concentration extends to the northeastern BAAP facility boundary in the elevated flow system. At the northeastern BAAP facility boundary, the elevated flow system appears to recharge and mix with the deeper regional system and the SO4 concentrations fall below the WES (250,000 $\mu g/\ell$), but remain above the WPAL (125,000 $\mu g/\ell$). As in the other areas of the installation, NIT concentrations were above the WPAL in many wells and above the WES in a few wells. The NIT appears to be higher in the elevated flow system downgradient from the Deterrent Burning Ground, although without any clear spatial pattern. The distribution of NIT could reflect the use of agricultural fertilizers in the area, as well as disposal activities.

It should be noted that SO4 is the only site related contaminant displaying a clear plume. However, the SO4 concentrations detected at the BAAP boundary exceed the WPAL, but do not exceed the WES. Further, SO4 is only regulated as a secondary or public welfare standard, not as a primary or public health standard. If groundwater from the northeastern portion of BAAP were to discharge to Wiegand's Bay there would be no substantial impact to Wiegand's Bay or the surrounding area.

Review of the BAAP quarterly groundwater data through September 1992 from the Deterrent Burning Ground and Existing Landfill identify the same principal contaminants as the RI data. SO4 is the principal contaminant detected in both the BAAP quarterly data and the RI data exceeding the WPAL and WES at selected monitoring wells. The SO4 data shows a clear contaminant plume. NIT was also found at concentrations above the WES and WPAL in the BAAP quarterly data. However, the high NIT concentrations occur both upgradient and downgradient of the site and, as such, cannot be directly attributed to the Deterrent Burning Ground as a source. The BAAP quarterly data shows some variability in CR concentrations with a high spike in 1989 to 1990 which has gradually decreased over time. This condition is similar to the CR detected during the RI. The BAAP quarterly data also indicates that specific conductance and hardness are increasing in selected wells.

Monitoring well ELN-89-02A has shown notable results in the BAAP quarterly data. This includes high concentrations of CR (up to 1,400 μg/l) and MEC6H5 (up to 1,700 μg/l). As previously discussed in this RI monitoring well ELN-89-02A appears to be contaminated with grout and is not functioning properly. The BAAP data also shows concentrations of CD and CR in most wells in this area exceeding the WES during the July 1989 and occasionally the September 1989 sample rounds.

26DNT was detected in both Rounds One and Two of the RI in monitoring well DBM-82-01 and was detected in the BAAP quarterly sampling round data in September 1990 in monitoring well DBN-82-01B (8.8 μg/l). The related SVOC, 24DNT was also detected in the BAAP quarterly sampling round data in September 1992 in monitoring well DBM-82-02 (0.23 μg/l). The DNT detects in the BAAP quarterly data occurred in only 1 of 15 sample rounds.

It should be noted that selected compounds detected during the two rounds of RI sampling were not detected during the BAAP quarterly sampling. 111TCE and 112TCE were generally not detected in the BAAP quarterly data but were detected in the RI data. These compounds were generally detected at concentrations below the detection limit of the BAAP quarterly data.

7.5 HUMAN HEALTH EVALUATION

7.5.1 Deterrent Burning Ground

The Deterrent Burning Ground is an inactive disposal site in the northeastern portion of BAAP. It is a man-made depression about 20 feet deep at the northern edge and approximately 2 acres in size (see Subsection 7.1.1). It is adjacent to the Existing Landfill which is in fact closed and capped. The area itself is old field growing into woodland and is surrounded by more established woods. A crop area lies beyond the woods to the north and fenced pasture beyond the southern woods. The burning pits have been capped with plastic and fill and are now well vegetated.

7.5.1.1 Identification of Compounds of Concern. Compounds of potential concern were identified for the Deterrent Burning Ground by applying the criteria listed in Subsection 4.2 to the laboratory analytical results for soil boring results to a depth of 12 feet bgs. No surface samples were taken because the waste pits have been capped. Appendix O, Table O-54 identifies all compounds detected, their frequency of detection, range of concentrations, and rationale for exclusion. Compounds selected as potential compounds of concern are listed with their exposure point concentrations in Table 7-17.

7.5.1.2 Exposure Point Concentrations. Exposure point concentrations for subsurface soil at the Deterrent Burning Ground, listed in Table 7-17, are maximum detected values because fewer then twenty samples were available. The rationale for selection of exposure point concentrations is given in Subsection 4.3.5.

Exposure point concentrations for volatiles and chemicals on PM10 particles are estimated by applying the calculation procedures described in Subsection 4.3.5. The results of the calculations are shown in Appendix O, Table O-56.

7.5.1.3 Human Exposure Assessment. Exposure to each chemical of potential concern were calculated for a hypothetical construction worker for oral and inhalation routes as described in Subsection 4.3.4. The area is too small and steep sided to be farmed and is not currently mowed or maintained. In any case, the contaminated areas are capped with plastic and covered with clean soil, so exposure to surface soil is not a complete pathway.

7.5.1.4 Risk Characterization. This subsection describes risk characterization.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3.4. Subchronic oral RfD values shown in Table 4-6 are used because of the short term of exposure. RfCs are listed in Table 4-9. Detailed calculations of chemical- and route-specific HQ values are shown in Appendix O, Tables O-55 and O-56. These HQ values were summed across all chemicals and across all pathways affecting the population. As shown in Table 7-18, the HI of 0.2 for ingestion does not exceed the USEPA target of 1. The inhalation route could not be fully evaluated because RfCs were not available for most of the COCs.

Cancer Risks. Excess lifetime cancer risks were evaluated as described in Subsection 4.5. Estimates of lifetime average daily intake were derived as described in Subsection 4.3.4. CSFs for oral and inhalation exposure employed are shown in Tables 4-7 and 4-8, respectively. Detailed calculations of chemical- and route-specific cancer risk estimates are presented in Appendix O, Tables O-55 and O-56.

The results are summarized in Table 7-18. The total estimated maximum excess cancer risk of 1×10^{-4} for the construction worker scenario falls within the target range and is attributable to ingestion of 24DNT, which contributes an individual excess risk of 1.4×10^{-4}. The excess risk for inhalation of particulates and volatiles, 4×10^{-8}, falls below the target range.

Risks from PB. PB was not detected above background levels at the Deterrent Burning Ground and so is not a site-related COC.

7.5.1.5 Summary of Risks at the Deterrent Burning Ground. Based on risk evaluations, the only chemical in soil at the Deterrent Burning Ground site that contributes to excess risk is 24DNT.

Based on assumed current and future human activities at this area of the BAAP site (i.e., future construction worker), there does not appear to be a noncarcinogenic health risk. There is an excess cancer risk of 1×10^{-4} associated with ingestion of soil contaminated with 24DNT.

7.5.2 Existing Landfill

The Existing Landfill, which is in fact no longer in operation, is located in the northeastern part of BAAP adjacent to the Deterrent Burning Ground. It received virtually all the uncontaminated (i.e., nonpropellant) waste generated at BAAP. The landfill was closed in accordance with WDNR requirements in the spring of 1989. A clean soil cap was placed over the landfill, effectively limiting direct contact, incidental ingestion or inhalation of contaminated soil, or exposure to nearby contaminants. Therefore, these routes of exposure were not evaluated. Although future maintenance activities may be performed on the cap, it is unlikely that the landfill will be disturbed by excavation so exposures to subsurface soil were not evaluated.

7.5.3 Evaluation of Groundwater

The nature and extent of contamination in groundwater at the Deterrent Burning Ground and Existing Landfill are discussed in detail in Subsection 7.4.2.4.5. Table 7-19 lists the COCs, frequency of detection, range of detected concentrations, and federal and state regulatory levels. NIT, CR, and HG are detected at concentrations that exceed both MCLs and WESs. BE levels exceed a concentration calculated to be protective at a target level of 10^{-6}. CD, PB, and SE are found at concentrations that exceed the WPALs but are below enforcement standard levels. MN, ZN, and SO4 exceed secondary drinking water standards and NA exceeds the federal reporting level. With the exception of SO4, all these inorganic compounds are detected sporadically and none has a spatial or temporal pattern indicative of a site-related contaminant plume. NIT, specifically, appears to be related to regional agricultural activities. 112TCE and 26DNT exceed WESs and appear to be part of a site-related plume.

7.5.4 Discussion of Uncertainties

Uncertainties involved in the risk assessment process are discussed in Subsection 4.6.

7.5.5 Summary

Carcinogenic risk to future construction workers at the Deterrent Burning Ground are estimated at 1×10^{-4} and are due to incidental ingestion of soil contaminated with 24DNT. There are no noncarcinogenic risks above the USEPA target level of 1. PB was not detected above background levels. 112TCE and 26DNT in groundwater exceed Wisconsin standards. BE exceeds a level calculated to be protective in groundwater. A number of other inorganics in groundwater exceed federal and state standards or WPALs, but are not judged to be part of a site-related plume.

7.6 BASELINE ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment for BAAP is to describe sensitive habitats and natural resource areas throughout the study area, focusing on the ecological communities at each BAAP site under investigation. In addition, baseline ecological effects associated with exposure to chemical constituents in environmental media at the facility are defined. The ecological assessment, conducted according to procedures outlined by USEPA, contains the following elements (USEPA, 1989a):

- Basewide Ecological Resource Areas (Subsection 2.2.6)
- Site Biological Characterizations (Subsection 7.6.1)
- Selection of Chemicals of Concern (Subsection 7.6.2)
- Ecological Risk Characterization (Subsection 7.6.3)

The general approach used to characterize ecological risks in this Baseline Ecological Assessment is summarized in Section 5.0.

7.6.1 Site Biological Characterization

Deterrent Burning Ground and Existing Landfill. The Deterrent Burning Ground and Existing Landfill are two distinct sites next to one another in the northeastern section of BAAP. Both sections are classified as plant facility tracts within the confines of BAAP (Hellewell and Mattei, 1983). The vegetation established in the area includes early successional-stage woodland and old-field herbaceous communities. Typical species within these plant associations include white ash (*Fraxinus americana*), bigtooth aspen, sweet clover (*Melilotus* sp.), and common milkweed (*Asclepias syriaca*). The tracts are established as improved grounds and are mowed and maintained. At the Existing Landfill, operation of earth moving equipment and trucks limits the density and species diversity of biota that inhabit the site. ABB-ES field personnel observed rabbits (*Sylvilagus floridanus*), field mice, red fox, red tail hawks, killdeer (*Charadrius vociferus*), and cow birds (*Molothrus ater*) in and adjacent to the northeast section of BAAP. Because of the lack of ponded water or wetland areas at this site, no aquatic receptors occur here.

The Deterrent Burning Ground and Existing Landfill are surrounded by wooded areas. The trees in the woodland community such as red oak and hickory can be expected to provide habitat for many mammal and bird species (Appendix P, Tables P-3 and P-4).

7.6.2 Selection of Chemicals of Concern

7.6.2.1 Deterrent Burning Ground. Waste pits at the Deterrent Burning Ground were covered with plastic and backfilled with soil. As a result, characterization of surface soils for COCs identification was not considered necessary at this site.

7.6.2.2 Existing Landfill. The Existing Landfill was closed and capped in 1988 in accordance with WDNR requirements. As a result, characterization of surface soils for COCs identification was not considered necessary at these sites.

7.6.3 Ecological Risk Characterization

The Deterrent Burning Ground waste pits have been capped with plastic and backfilled with soil. The only surface soil data available for the Deterrent Burning Ground is from a sample, DBB-91-01, which was collected at a depth of 2 feet. Although some burrowing animals and soil invertebrate fauna could be exposed to soil contamination at this depth, it is inappropriate to conduct a quantitative assessment on such limited data. 24DNT was detected at a concentration of 2,700 μg/g in this sample and ecological receptors could be at risk from exposure to this compound if this concentration is representative of general conditions.

7.6.4 Ecological Risk Assessment Conclusions

Although a quantitative risk characterization of the Deterrent Burning Ground was not conducted, an evaluation of the analytical data collected from a single soil boring sample indicates that exposures by terrestrial ecological receptors to 24DNT could be sufficient to cause risk. Because the sample was collected at a depth of 2 feet bgs and because of the limited amount of data, it cannot be determined whether detected concentrations are reflective of general conditions at the Deterrent Burning Ground. There is no aquatic habitat associated with this site and no exposures by aquatic organisms is anticipated.

No ecological risk is anticipated at the Existing Landfill because the landfill cap is expected to limit exposures by ecological receptors to any potential subsurface contamination.

7.7 CONCLUSIONS OF THE BASELINE HUMAN HEALTH AND ECOLOGICAL EVALUATIONS

The results of the human health assessment indicate that remedial action objectives aimed at reducing exposure to or concentrations of 24DNT in soil should be developed as part of the FS.

The cap and closure of the Existing Landfill limit exposure to contaminated subsurface soil. This cap is scheduled for repair during 1993.

Response objectives for groundwater should limit concentrations of, or exposure to, 26DNT, 112TCE, and BE.

8.0 NITROGLYCERINE POND, ROCKET PASTE AREA, AND NEW ACID AREA

The Nitroglycerine Pond, Rocket Paste Area, and New Acid Area are located next to one another in the north-central portion of BAAP. These sites share similar site settings along with geologic and hydrogeologic environments, and are discussed together in this section.

8.1 CURRENT AND PAST DISPOSAL PRACTICES

8.1.1 Nitroglycerine Pond

The Nitroglycerine Pond is a small, unlined basin, approximately 160,000 ft^2 in area with a maximum depth of 3 to 5 feet. The pond has been used since sometime between 1944 and 1949 to hold cooling water and process wastewaters generated in the NG manufacturing area during production periods (see Figure 8-1). According to the Olin Point Source Pollution Engineering Study, wastewater was neutralized at the plant before being discharged into the pond. It is possible that NG and other contaminants, such as NIT, SO4, NA, CA, and chlorides, were present in the discharge; however, actual wastewater characterization data are not available.

The Nitroglycerine Pond is part of the major drainageway draining the central manufacturing and storage areas of BAAP. In addition to the main pond, there is a large, low-lying area immediately east of the pond that appears to have received overflow from the pond, possibly during production periods. A drainage ditch also drains the Nitroglycerine Pond at its southern end; flow is to the Rocket Paste Pond south of the Nitroglycerine Pond. A plan of the NG manufacturing area, including the Nitroglycerine Pond and overflow pond, is shown in Figure 8-1.

The NG facility and the Rocket Paste production areas are not visible in the 1944 aerial photographs, indicating these facilities were constructed sometime after March 1944.

The ponds and overflow ditches at the southwestern edge of the NG facility are dry but clearly visible in the 1949 photographs. The 1955 photographs show water in both the main pond along the southeastern corner and the overflow pond south of the facility. The 1962 photographs show water only in the main pond. The 1968 photographs indicate that the main Nitroglycerine Pond overflowed to the east and flooded the adjacent depression. This depression does not appear to have an outflow channel. The photographs also indicate that maximum ponding as observed in the aerial photographs could have occurred sometime before June 2, 1968. No surface water is visible in the overflow pond in the 1968 photographs. Water is clearly visible in both the main pond and overflow pond in the 1986 photographs.

8.1.2 Rocket Paste Area

The Rocket Paste Area is located in the central portion of BAAP, immediately south of the Nitroglycerine Facility and east of the Johnstown terminal moraine (Figure 8-1). The Rocket Paste Area contained numerous facilities for blending, pressing, milling, and drying rocket paste. The Rocket Paste Area is generally divided into two sections: The East Rocket Paste Area, active in World War II and the West Rocket Paste Area, active after World War II. In addition, the Rocket Paste Pond, located between the Rocket Paste Area and Nitroglycerine Pond, is discussed in this section. Rocket paste is double-based plasticized propellant used to fuel solid-fuel rockets. During propellant manufacturing operations, waste propellant in the form of a reddish orange paste accumulated in the Rocket Paste Pond and many parts of the ditches. Process wastewaters transported via these ditches consisted of makeup water used in mixing and formulating rocket paste, as well as cooling and washdown water, according to Olin's Point Source Pollution Engineering Study (Olin, 1984). The rocket paste reportedly contains 1.2 percent each of PB salicylate and PB ethylhexoate, in addition to NG and NC (Piercy, 1977). Visible paste was removed and burned at the Propellant Burning Ground after BAAP went on standby status.

Stormwater and process wastewater from the Rocket Paste Area have been transported via a series of drainage ditches (Figure 8-1). The ditches have a typical width of 5 to 30 feet and a typical depth of 3 to 12 feet. In the West Rocket Paste Area, interconnecting drainage ditches transported water and wastewater to a drainageway which extends south through the Magazine Area more than 2 miles to the third Settling Pond (i.e., Pond 3) near the southern boundary. In addition, during past periods of production, process wastewater from the north end of the West Rocket Paste Area was discharged to ditches which drained to the Rocket Paste Pond. The MEP describes the Rocket Paste Pond as an unlined catch basin 6 to 12 inches deep that serves as a settling basin for suspended rocket paste particles in the liquid waste streams (Tsai et al., 1988). The Rocket Paste Pond is approximately 45,000 ft^2 in area. The pond also received process wastewater from the NG manufacturing area to the north. Effluent from the pond discharges into a ditch which connects with the ditch draining the West Rocket Paste Area. In the East Rocket Paste Area, stormwater and process wastewater have been transported via interconnected drainage ditches to settling basins located north and south of the East Rocket Paste Area.

8.1.3 New Acid Area

The New Acid Area is in the north-central portion of the BAAP site (see Figure 8-1). As part of the overall modernization program, construction of a new nitric/sulfuric acid complex was initiated at BAAP during 1973 to 1974. The acid complex consists of a 400-ton per day Nitric Acid Plant, a 360-ton per day 40 percent Oleum/Sulfuric Acid Recovery Plant, and a Nitric Acid/Sulfuric Acid Concentration Plant with capacities of 560 tons per day of 100 percent nitric acid and 1,210 tons per day of 100 percent sulfuric acid, respectively. Process prove outs of the Nitric Acid Plant, Oleum/Sulfuric Acid Recovery Plant, and Nitric Acid/Sulfuric Acid Concentration plants were completed during 1979 to 1981. In this area, according to the MEP, several spills of nitric and sulfuric acids have occurred in the storage and loading areas since 1979 (see Figure 8-1). As shown in Table 8-1, sulfuric acid spills occurred on April 12, 1979; June 20, 1981; June 18, 1982; and October 22, 1982. Nitric acid spills occurred on September 25, 1981, and June 28, 1982. There was also a nitric acid spill on October 7, 1981, and a mixed acid spill on November 1 and 2, 1984. In all cases, most of the spilled acid was neutralized. Sodium hydroxide, sodium carbonate, and/or lime were used to neutralize acid spills or leaks (Kearny, 1987).

An unlined lagoon (200 by 200 feet) was created in 1976 on the western side of the New Acid Area to collect neutralized acidic wastewater from acid production. Nitric and sulfuric acid production, concentrating, and reprocessing waste streams were neutralized by caustic soda or hydrated lime before discharge into the lagoon. Acid from spills within the complex also flowed into the lagoon and were neutralized. The lagoon, with a capacity of 250,000 to 300,000 gallons, was established by berming clayey soils obtained within the plant. The retention area provided the necessary reaction and stabilization time, while wastewater was neutralized by either caustic soda, sodium carbonate, or hydrated lime. .

The unlined lagoon has been closed since late 1986. Closure was accomplished by draining accumulated wastewater, grading the exterior clay berms and leveling the bottom sediments, and covering the dried sediments with a compacted layer of clay followed by soil and topsoil, which was graded, seeded, and mulched. The closure plan was approved by WDNR on February 19, 1985. Closure activities began in May 1985, ending in the fall of 1986 (Tsai et al., 1988).

Review of the historical aerial photographs shows the new acid facility only in the 1976, 1978, and 1980 high altitude photographs. In addition to the plant area, a square barren area west of the plant is also visible in the 1976 photographs. Because of the scale of the 1976 photographs, details of the barren area were not available. This area is likely the unlined lagoon.

8.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

Table 8-2 summarizes the field activities performed at the Nitroglycerine Pond, Rocket Paste Area, and New Acid Area.

8.2.1 Sediment and Surface Water Sampling

During the RI field investigation, 70 surface soil samples, eight sediment samples, and four surface water samples were collected from the Nitroglycerine Pond, Rocket Paste Pond, and Rocket Paste Area for laboratory and field analyses. The sediment samples were collected from locations that contained water at the time of sampling or were immediately adjacent to the shoreline. Samples collected from dry ponds and ditches are considered surface soil samples; however, this material was likely deposited in the ditches as sediment when the ditches contained water.

8.2.1.1 Nitroglycerine Pond. Six discrete sediment samples and four surface soil samples were collected from the Nitroglycerine Pond area at the approximate locations illustrated in Figure 8-1. The samples were collected from flooded and formerly flooded areas as follows. Surface soil samples NPS-91-01, collected east of the pond in the dry overflow pond area and NPS-91-02, collected in the dry ditch between the Nitroglycerine Pond and the overflow pond area, were excavated from 1 to 4 inches bgs, using a tulip bulb planter. Samples were placed on an aluminum pan for handling before being transferred to appropriate containers. These samples consisted of fine sands and silts that were collected from dry, but formerly flooded, areas.

Six sediment samples, NPS-91-03 through NPS-91-08, were collected using a stainless steel spoon and aluminum pan from the pond at depths of 1 to 6 inches, and were arranged to create a northeast to southwest profile of the pond. These samples consisted of wet, plastic silty clay soils collected in areas adjacent to the pond shore that are typically flooded. Two surface soil samples, NPS-91-09 and NPS-91-10, were collected from the dry ditch south of the pond. These samples were also collected with a tulip bulb planter at a depth of 1 to 4 inches. These samples consisted of dry fine sand and silt.

In 1989 a series of 10 sediment and surface soil samples (NPS-89-01 through NPS-89-10) were also collected at the Nitroglycerine Pond. Locations of these samples correlate to the 1991 samples.

8.2.1.2 Rocket Paste Area. Sixty-six surface soil samples and two sediment samples were collected from the drainage ditches and Rocket Paste Area. Approximate locations of the samples are shown in Figure 8-1. Discrete samples were collected using a tulip bulb planter from a depth of 1 to 6 inches bgs. Sample material was placed on an aluminum pan for mixing before being transferred to appropriate containers.

Two sediment samples, RPS-91-01 and RPS-91-02, were collected in the Rocket Paste Pond. These samples were collected below approximately 0.5 foot of water. Two surface soil samples, RPS-91-03 and RPS-91-04, were collected from the drainage ditch extending south from the Rocket Paste Pond. Twenty-six surface soil samples, RPS-91-05 through RPS-91-10 and RPS-91-16 through RPS-91-35, were collected from the bottom of drainage ditches in the West Rocket Paste Area, which was active during the Korean and Vietnam conflicts. RPS-91-16 was collected near monitoring well S1118 at the confluence of the West Rocket Paste Area drainage ditches. Thirty-eight surface soil samples, RPS-91-11 through RPS-91-15 and RPS-91-36 through RPS-91-68, were collected from the bottom of drainage ditches in the East Rocket Paste Area, which was active only during World War II. RPS-91-15 was collected near RPM-91-01 at the confluence of the East Rocket Paste Area drainage ditches.

Two surface water samples (RPW-91-01 and RPW-91-02) were collected from the Rocket Paste Pond as illustrated in Figure 8-1. Samples were collected directly into appropriate sample bottles.

8.2.2 Monitoring Well Installations

Over the course of the RI field activities, four monitoring wells were installed by John Mathes Associates, Inc., of St. Louis, Missouri, and Layne Environmental, Inc., of Tempe, Arizona, under subcontract to ABB-ES. These wells supplement the five existing wells within the Nitroglycerine Pond area and Rocket Paste Area, six wells at the New Acid Area, and seven wells south and east in the Magazine Area. All monitoring wells are constructed with flush-threaded 4-inch, Schedule 80 PVC and have either 10- or 20-foot well screens (0.010 in. machine-slotted openings). Sandpack placed around the well screens extends approximately 5 feet above the screen. A 5-foot bentonite seal was placed above the sandpack. With the exception of the New Acid Area wells, a Type II cement/bentonite grout was placed above the bentonite pellet seal and extends to the ground surface. Borings drilled for monitoring well installation were advanced with 9- or 10-inch diameter drill-through-casing hammer or dual-wall driven casing. Both techniques use air circulation for soil cuttings return. Wells installed before RI activities were drilled using mud-rotary techniques where a drilling mud was circulated for soil cuttings return. Well development for wells installed by ABB-ES was accomplished with a submersible pump that was raised and lowered across the screened section of the well. A minimum of five well volumes of water was removed during the development process. Appendix D contains records of well development activities. All wells were sampled to monitor for the presence of chemicals in groundwater. Selected wells were tested to estimate hydraulic properties of the aquifer.

One shallow water table well was installed near the Nitroglycerine Pond during the RI. The approximate location of this well is shown in Figure 8-2. Based on a review of existing information relative to the Nitroglycerine Pond and Nitroglycerine Area, the water table well (NPM-89-01) was placed approximately 700 feet south of the Nitroglycerine Pond and Nitroglycerine Area. A summary of new well information and siting rationale is included in Table 8-3.

The locations of three wells installed in the Rocket Paste Area during the RI are shown in Figure 8-2. Based on the relatively high solubilities of expected contaminants and low attenuation of sandy soils in this area, well RPM-89-01 was placed approximately 2,400 feet southeast (downgradient) of the Rocket Paste Pond. RPM-89-02 was placed in the East Rocket Paste Area. RPM-91-01 was placed downgradient of a small retention basin in the southeast portion of the East Rocket Paste Area.

8.2.3 Permeability Testing

To obtain an assessment of permeability variations within the unconsolidated aquifer at the site, a series of rising-head slug tests was performed on two new shallow monitoring wells at the Rocket Paste Area (Table 8-4). Water displacement for the rising-head tests was accomplished by physical displacement of water with a cylindrical slug. The water column was depressed by displacing water with a 2-inch diameter cylinder lowered 5 to 8 feet below the static water level. After allowing the water level to recover to its static condition, the slug was quickly withdrawn, and data gathered as the water rose to its static level.

The rate of water level rise was recorded with a 20-psi pressure transducer and Hermit 2000 data logger, both manufactured by In-Situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which can result in water level rebound above the static background level.

Generally, two to five tests were performed on each well to assess the variations associated with each test, evaluate any inertial effects associated with each well, and apply the maximum stress possible at each well. Rising head test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected tests were also evaluated using Bouwer and Rice (1976) techniques (see Appendix I). Results of the Bouwer and Rice analyses compared favorably with Hvorslev results. Results of these analyses are summarized in Subsection 8.3.

8.2.4 Groundwater Sampling

Table 8-5 lists the nine wells within the Nitroglycerine Pond and Rocket Paste areas, six wells in the New Acid Area, and seven additional wells to the south and east in the Magazine and Southeast Boundary Area that were sampled during the RI. As part of the RI, ABB-ES conducted two rounds of groundwater sampling and analyses on these wells. Round One was conducted from November to December 1991 and Round Two was conducted from April to May 1992. Groundwater samples were submitted to A. D. Little Analytical Laboratories in Cambridge, Massachusetts (a USATHAMA-certified laboratory) for laboratory analysis.

Before collecting groundwater samples, each well was measured for water level to the nearest 0.01-foot and well depth to the nearest 0.1 foot, and then purged of five well volumes of water. Water level measurements were obtained at each well using an electronic water level meter accurate to 0.01 foot. Water level data are presented in Appendix G and discussed in Subsection 8.3.3. Well depths were sounded to assess sedimentation. The new and existing wells were purged with a submersible pump to remove stagnant water in the well casing. Purge volumes varied depending on well recharge rates. Generally, five times the sandpack and well volume were purged before sampling. Purge water was monitored in the field at the time of collection for temperature, pH, and specific conductance. Variances were documented and recorded on field data sheets found in Appendix G. During the groundwater field sampling effort, equipment was decontaminated by steam-cleaning with water from Production Well No. 2.

8.2.5 Summary of Chemical Analysis Schedule

Surface soil, sediment, surface water, and groundwater samples from the Nitroglycerine Pond, Rocket Paste Area, and New Acid Area were selected for laboratory analysis.

The following subsections summarize the chemical analysis schedule.

8.2.5.1 Laboratory Analytical Program. Tables 8-6, 8-7, and 8-8 summarize the surface soil, sediment, surface water, and groundwater analytical matrices for the Nitroglycerine Pond, Rocket Paste Area, and New Acid Area. Chemical analytical methods are described in Subsection 4.2 of the Sampling Design Plans.

ABB-ES' analytical subcontractors: A. D. Little, EA, and DataChem, used procedures consistent with the USATHAMA CLASS program for analysis of groundwater, soil, surface water, and sediment samples. Analysis of general water quality parameters (i.e., HARD, ALK, and TDS) do not require certification.

Reference information on the basis of USATHAMA methodology is contained in Appendix L. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings within certified reporting limits.

The analyte matrix is based on the soil and water data presented in the MEP data and the substances reportedly disposed at these sites (Tsai et al., 1988). Because of the potential for elevated metals to limit disposal options for soils at these locations, selected samples were submitted for analysis of TCLP extractable PB, CD, CR, and HG. Results of the TCLP analyses being promulgated for evaluation of toxicity as a component of RCRA (40 CFR 268 Appendix I), will be used in this report for estimating the leachable metal concentrations from soil samples.

Samples from three wells at the Nitroglycerine Pond were tested for BN/A, NAMs, and DNTs. Nitroglycerine and its degradation products are the primary analytes; analysis of samples for these compounds was requested for surface water, sediments, and groundwater. Stable breakdown products can also include NH3. Ammonia was added as a nitroglycerine indicator compound to the analytical program for the Nitroglycerine Pond sediment samples and the Nitroglycerine Pond and Rocket Paste Area groundwater samples.

In the Rocket Paste Area, sediment samples were tested primarily for DNTs, NAMs, NG, BN/A, anions, and four metals (CD, CR, HG, and PB) expected to be present in propellants and rocket paste. TCLP was also used on most sediment samples to evaluate leaching potential of CD, CR, HG, and PB. Groundwater samples were tested for metals (CD, CR, HG, and PB), anions, indicator parameters, VOCs, and NG.

Groundwater samples from the New Acid Area were analyzed for metals (CA, NA, CD, PB, and NI), anions (NIT, CL, and SO4), indicator parameters (HARD, ALK, and TDS), and VOCs.

8.2.5.2 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data from A. D. Little, EA, and DataChem, and the geotechnical data from the field drilling program.

Appropriate field data records were completed for each groundwater, surface water, and sediment sample. Field data records can be found in Appendices D (surface water and sediment) and G (groundwater). These sheets contain specific information on each sample such as the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, sampling technique, analyses required, and sample preservation. A field notes section provides for additional site information sampling personnel may need to include. Each well has a Monitoring Well Installation Data Record that documents structural details.

When soil samples were taken from test borings, a Field Boring Log was completed. On this log, the driller and geologist record notes from the soil sampling event. The Field Boring Log and the field notes are both kept on file by ABB-ES. Samples were given unique site IDs for sample identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data was entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both ABB-ES' home office and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map Files, Geophysical Groundwater Stabilized Files, Geophysical Field Drilling Files, Geotechnical Well Construction Files, Chemical Groundwater Files, Chemical Surface Water Files, Chemical Soil Files, and Chemical Sediment Files.

Chain-of-custody records along with ARFs were used to coordinate transfer of samples from field sampling locations to the laboratory. Samples were divided into sample lots according to method, matrix, and analytical QC groups.

8.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The Nitroglycerine Pond, Rocket Paste Area, and New Acid Area are located next to one another in the central production area of BAAP along the crest and east of the Johnstown Moraine. As such, these sites share similar geologic and hydrogeologic environments.

8.3.1 Surface Water Hydrology

The Nitroglycerine Pond area, located east of the Johnstown Moraine, has an irregular surface topography with numerous small hills and isolated depressions. Topographic relief in the area is approximately 30 feet. The natural drainage network is poorly developed except for the man-made drainage ditch transecting the site area from north to south and flowing through the Nitroglycerine Pond. Most surface water runoff from the central production facilities, including the Nitroglycerine Pond and Rocket Paste areas are routed to this ditch. At the Rocket Paste Area, site construction activities have leveled the surface topography leaving only a few small hills and a series of man-made drainage ditches.

The principal surface water features in these areas, illustrated in Figure 8-1, include the Nitroglycerine Pond, Rocket Paste Pond, and a series of man-made drainage ditches that flow through the ponds and transect the sites. The Nitroglycerine Pond is a small unlined basin that appears to occupy a preexisting natural depression that was recontoured to meet the needs of the facility. A low area bordering the pond to the east also received overflow from the pond in the past (see Subsection 8.1 for details).

The Rocket Paste Pond is another small unlined basin south of the Nitroglycerine Pond. Like the Nitroglycerine Pond, the Rocket Paste Pond appears to occupy a natural depression that has been modified to meet the drainage needs of the facility. This basin received surface water runoff from the northwestern portion of the Rocket Paste Area as well as overflow water from the Nitroglycerine Pond. Both ponds exist as perched water bodies, probably due to the presence of a layer of fine-grained sediments in the bottom of each pond and contain water most of the year.

Most surface water runoff from the central production and storage facilities of the Nitroglycerine Pond and Rocket Paste areas is routed to a series of man-made drainage ditches that originate near the Deterrent Burning Ground and transect these sites from north to south. Water from the Rocket Paste Pond and West Rocket Paste Area eventually discharges to Settling Pond 3 along the southern boundary of BAAP. Water from the East Rocket Paste Area discharges to depressions located to the north and south of this area. The man-made drainage ditches were not designed to collect runoff from nonproduction areas. Runoff from these areas discharges to isolated depressions that are common in the area east of the Johnstown Moraine.

The New Acid Area is located on the crest of the Johnstown Moraine. Drainage from this site has been routed to the west. Between 1976 and 1986 a seepage lagoon just west of the New Acid Area collected wastewater and spills. New Acid Area monitoring wells (NAN) are located immediately south of this lagoon (Figure 8-1).

8.3.2 Geology

Soil borings and monitoring wells installed at the Nitroglycerine Pond, Rocket Paste, and New Acid areas generally have encountered a stratigraphic sequence similar to that observed over much of the area east of the Johnstown Moraine. Unconsolidated soil deposits appear to range between 200 and 250 feet in thickness and are predominantly variably textured coarse-grained soils. Figure 8-2 shows the locations of monitoring wells installed in this area and the orientation of geologic cross section J-J'. Geologic cross section J-J' is presented in Figure 8-3.

Surficial soils in this area are composed of fine-grained loess and granular fill. The loess is composed of windblown fine sand, silt, and clay and is typically accompanied by an overlying organic-rich topsoil. Where encountered in this area, loess was described as reddish-brown to gray clayey silt and fine sand that ranged from 7 to 19 feet thick.

At four locations (i.e., RPM-89-01, RPM-91-01, S1119, and S1124), only granular fill was encountered at the ground surface. It is likely that the fine-grained loess and topsoil were removed from these areas during site construction activities. Fill soils were typically described as tan-to-brown, fine-to-coarse sand with little to some gravel, silt and clay, and occasional cobbles.

Underlying the loess and surficial fill soils, variably textured sands and gravels were encountered. At several locations (i.e., S1118, S1124, RPM-89-01, RPM-89-02, and RPM-91-01), very coarse gravel, cobble, and boulder zones were encountered immediately below the surface soils. This condition is typical of ablation tills where coarse-grained soils were deposited by melting glacial ice. At other locations, sands and gravels were encountered below the loess. These soils were typically described as light gray-to-brown, medium-to-fine sand with some gravel and silt.

A second coarse gravel and cobble layer was encountered at a depth of 65 to more than 130 feet bgs (i.e., an elevation of 815 to 750 feet MSL). As Figure 8-3 indicates, this unit appears to be somewhat thinner with a higher elevation to the south and typically becomes thicker with a lower elevation to the north. Well-rounded gravel observed in this unit suggests a glacial-fluvial origin.

It should be noted that silt and clay layers observed north of this area near the Deterrent Burning Ground and Existing Landfill (see Section 7.0) were not encountered in borings at the Nitroglycerine Pond, Rocket Paste, or New Acid areas. In addition, water table elevations conform to the regional flow pattern, showing no evidence of an elevated condition. These conditions indicate that clay and silt deposits observed to the north do not extend into this region.

Although bedrock was not encountered in any borings installed in this area, regional information suggests the bedrock surface is at an elevation of 600 to 650 feet MSL and is likely composed of sandstone belonging to the Dresbach Group.

8.3.3 Hydrogeology of Unconsolidated Sediments

As discussed in Subsection 8.3.2, the presence of a fine-grained silty loess immediately below the ground surface generally restricts the infiltration of precipitation, thereby limiting recharge to the underlying groundwater flow system to approximately 5 to 7 inches per year. However, where the loess unit has been stripped from the site because of construction activities, infiltration rates and corresponding recharge rates may be higher, approximately 7 to 9 inches per year. Recharge rates could be higher beneath the Nitroglycerine Pond and Rocket Paste Pond, which hold water throughout much of the year.

Underlying the fine-grained surficial soils is a thick sequence of sand and gravel. In this area, the upper 100 to 130 feet of the unit is unsaturated and constitutes a considerable vadose zone. Below the water table, an additional 120 to 170 feet of saturated sand and gravel constitutes the unconsolidated sand and gravel aquifer.

Hydraulic conductivity testing, based on in situ slug withdrawal tests, were performed at wells RPM-89-01 and RPM-89-02 by ABB-ES and at wells S1118, S1119, and S1124 by Warzyn. The results of tests performed by ABB-ES are summarized in Table 8-4 and show a range of hydraulic conductivity from 1×10^{-1} to 2×10^{-1} cm/sec. These results are somewhat higher than the average for other tests conducted east of the terminal moraine (see Subsection 7.3.3). The raw data, graphical plots, and calculations for tests conducted by ABB-ES are in Appendix I. The raw data and calculations for tests conducted by Warzyn are in EEI, 1981.

8.3.4 Groundwater Movement

Figure 8-4 shows a water table contour plan for the Nitroglycerine Pond, Rocket Paste, and New Acid areas generally indicating groundwater flow from north to south. The regional water table, as illustrated in Figure 2-3, shows groundwater north of this region flowing to the southeast but turning to the south as it flows through the New Acid and Nitroglycerine Pond areas.

These sites lie at the southern extent of an area of flat water table gradients that occurs over much of the northeastern and central portions of BAAP. These flat gradients reflect the influence of the Lake Wisconsin Reservoir located to the east and south. The water table drops only 2.7 feet throughout this area, resulting in a horizontal gradient of 0.0008 ft/ft.

Groundwater flow velocity ranges from 240 to 330 ft/yr. The higher velocities likely reflect conditions associated with more permeable zones, while the lower velocities are likely associated with less permeable zones. Permeability estimates are based on slug test data only; no aquifer tests were performed in this area.

8.4 NATURE AND EXTENT OF CONTAMINATION

8.4.1 Introduction

The contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in surface water, surface soil, sediments and groundwater at the Nitroglycerine Pond, Rocket Paste, and New Acid areas of BAAP. Chemicals that represent site-related contamination were identified based on the evaluations of surface soil, sediment, groundwater, and surface water analytical results as compared to background concentrations of these chemicals detected in site soil and water as well as the use of these chemicals during past activities at these sites.

Analytical data collected before January 1988 were summarized in the MEP (Tsai et al., 1988). These data contained inconsistencies because of the use of differing analytical methods, sampling techniques, and protocols. However, these data are used to augment the description of contaminant nature, distribution, and behavior.

Chemical data tables downloaded from the IRDMIS are contained in Appendix K. Appendix L details specific results of the data quality assessment. This includes (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, (2) a listing of the USATHAMA-certified analytical methods used by the subcontractor laboratories, (3) a summary of the laboratory quality control sample results and impact on associated field sample results, and (4) a summary of nontarget, library-searched VOC and SVOC compounds detected in the RI analytical program, and (5) a summary of the USATHAMA-approved laboratory control charts.

Within this section, results of chemical analyses are presented by medium (i.e., surface water, surface soil, sediment, and groundwater). Chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). Indicator parameters (nonspecific measurements that generally characterize water quality) are used, where appropriate, to assist in site-specific data interpretation. The indicator parameters measured in this program were HARD, ALK, and TDS. Chemical-specific numerical standards and criteria used to evaluate chemical data are listed in Table 3-3, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WES, and WPALs.

Table 8-9 summarizes surface soil and sediment laboratory analytical results, Table 8-10 summarizes surface water laboratory analytical results and Table 8-11 summarizes groundwater laboratory analytical results. These tables list analytes with detectable concentrations in one or more of the samples. The following paragraphs comprise a summary and overview of the findings of the contamination assessment. Detailed results and interpretations are contained in Subsections 8.4.3.

Nitroglycerine Pond. The chemicals identified frequently and/or at concentrations greater than background in both sediments and surface water at the Nitroglycerine Pond were PB, HG, and NH3. The surface soil in the ditch between the Nitroglycerine Pond and the Rocket Paste Pond contained the same chemicals identified in the Nitroglycerine Pond except that the PB concentrations were substantially higher.

Rocket Paste Pond. The chemicals identified frequently and/or at concentrations greater than background in the sediments at the Rocket Paste Pond were PB, HG, NG, NNDPA, and SO4. The surface water also contained PB and SO4 at concentrations that appear to be above background concentrations.

Rocket Paste Area. The chemicals identified frequently and/or at concentrations greater than background in the surface soil in the numerous ditches throughout the area were PB, DNTs, NG, NAMs, phthalates, and several polynuclear aromatic hydrocarbons. The groundwater at several locations in the Rocket Paste Area contains concentrations of PB, SO4, ALK, and TDS greater than background.

New Acid Area. The analytes identified frequently and/or at concentrations greater than background in the groundwater were NO3 and SO4.

8.4.2 Contamination Assessment

The Nitroglycerine Pond is just north of the Rocket Paste Area and connected to it via drainage ditches. Historically and for convenience, the Rocket Paste Area is divided into Eastern and Western areas. The Nitroglycerine Pond is connected to the Western Rocket Paste Area by a drainage ditch flowing southward from the Nitroglycerine Pond through the Rocket Paste Pond and into the Western Rocket Paste Area. The Eastern Rocket Paste Area is somewhat separated from the Nitroglycerine Pond and Western Rocket Paste Area and, according to the MEP, its use was discontinued before the use of the Western Rocket Paste Area was begun (Tsai et al., 1988). The New Acid Area is located west of the Nitroglycerine Pond.

8.4.2.1 Surface Soils and Sediments.

Nitroglycerine Pond. Previous studies of surface soil and sediments in the Nitroglycerine Pond and the Western Rocket Paste Area are summarized in the MEP (Tsai et al., 1988). All previous sediment samples were taken from the drainage ditch connecting these two areas (see Figure 8-1). Highlights of the previous sampling efforts are briefly discussed in the following paragraph.

PB exceeded the EPTOX threshold value (TV) for two samples (i.e., 484-211, and 484-214) just north of the Rocket Paste Pond along the drainage ditch (Daubel, 1986; and Hellewell, 1983). The remaining samples were collected further downstream and did not exceed the EPTOX TVs. In three samples (i.e., S1408, RAD-16, and RAD-19), PB extract concentrations exceeded 1,000 mg/ℓ. Ayres Associates analyzed samples for 24DNT, 26DNT, DEP, DPA, 2NNDPA, NC, and NG, but none of these chemicals were detected (Ayres Associates, 1984).

Ten sediment and surface soil samples (i.e., NPS-91-01 through NPS-91-10) were collected by ABB-ES personnel from the Nitroglycerine Pond Area and its immediate drainage ditch area (see Figure 8-1). The samples were analyzed for total metals (i.e., CD, CR, HG, and PB), NG and NH3.

At the Nitroglycerine Pond, NG was detected at 9.39 μg/g and 15.8 μg/g in surface soil samples NPS-91-09 and NPS-91-10 collected from the drainage ditch leading south from the Nitroglycerine Pond. NG was not detected above the certified reporting limit in the surface water and sediment samples collected from the Nitroglycerine Pond. NG was detected in the drainage ditch leading from Nitroglycerine Pond to the Rocket Paste Pond. The NG distribution in surface soil and sediment is illustrated in Figure 8-5.

NH3 was detected in all samples collected at concentrations that ranged from 2.28 μg/g to 72.5 μg/g.

CD was not detected above background value. HG was detected above background concentrations in all but one of the samples collected from the drainage ditch between the Nitroglycerine Pond and the Rocket Paste Pond (NPS-91-10). The concentrations ranged from a low of 0.159 μg/g at NPS-91-02 to a high of 20 μg/g at NPS-91-05. HG was not detected in the surface soil from the ditch at NPS-91-10. The high HG concentrations were confined to the Nitroglycerine Pond samples (Figure 8-6). HG concentrations were generally lower or below the certified reporting limit downstream at the Rocket Paste Pond and associated ditches. PB was detected in all sediment samples collected from the bottom of the Nitroglycerine Pond at concentrations that ranged from 32 to 270 μg/g. PB was detected in the immediate drainage ditch area south of the Nitroglycerine Pond at concentrations significantly higher than were detected in the sediments within the pond (2,000 μg/g at NPS-91-09 and 10,000 μg/g NPS-91-10). PB was also detected in the overflow pond (NPS-91-01 and NPS-91-02) at concentrations of 410 and 110 μg/g, respectively. PB concentrations illustrated in Figure 8-7 indicate the lowest concentrations at the center of the Nitroglycerine Pond and higher concentrations at the margins of the pond and in the drainageway leading south toward the Rocket Paste Pond.

<u>Rocket Paste Pond</u>. Two sediment samples (RPS-91-01 and RPS-91-02) were collected by ABB-ES from the Rocket Paste Pond and two surface soil samples (RPS-91-03 and RPS-91-04) from the drainage ditch that carries the discharge from the pond into the Western Rocket Paste Area. The samples were analyzed for total and TCLP metals (CD, CR, HG, and PB), NG, NIT, SVOCs, DNTs and SO4.

At the Rocket Paste Pond, NG was detected above the certified reporting limit in sample RPS-91-01 at 1.76 μg/g. NNDPA was detected above the certified reporting limit in samples RPS-91-01 and RPS-91-02 at 4.98 and 0.738 μg/g, respectively.

CR was detected above background at RPS-91-02 and PB was detected above background at all four sample locations (RPS-91-01 through RPS-91-04). HG was detected at RPS-91-01 and RPS-91-02 near background levels and was not detected at RPS-91-03 and RPS-91-04. CD was not detected at any of the four sample locations. NIT was detected near background levels at all four sample locations. SO4 was detected above background levels at all four sample locations. SO4 was significantly higher in the sediment samples from the pond (RPS-91-01 and RPS-91-02).

<u>Rocket Paste Area</u>. Twenty-six additional surface soil samples (RPS-91-05 through RPS-91-10 and RPS-91-17 through RPS-91-35) were collected from drainage ditches in the West Rocket Paste Area. One sample (RPS-91-16) was collected downstream of the confluence of drainage ditches in the West Rocket Paste Area. Thirty-eight samples (i.e., RPS-91-11 through RPS-91-15 and RPS-91-36 through RPS-91-68) were taken from the East Rocket Paste Area. Figure 8-1 illustrates sampling locations. These surface soil samples were analyzed for: total metals (i.e., CD, CR, HG, PB), NAMs, SVOCs, DNTs, NG, NIT, and SO4.

Generally, the data indicate that NNDPA, PB, NG, and 24DNT are the principal contaminants at this site. Overall contaminant levels are lower in the West Rocket Paste Area. This likely reflects the excavation of ditches in the West Rocket Paste area which took place during the 1970s when the facility was deactivated.

SVOC analyses were conducted on all surface soil samples in the Rocket Paste Area. Generally, the detected contaminants can be grouped into polynuclear aromatic hydrocarbons and phthalates. Individual polynuclear aromatic hydrocarbon concentrations did not exceed 2.13 μg/g.

In the East Rocket Paste Area, polynuclear aromatic hydrocarbons were detected in 13 of 38 samples with a maximum concentration of 2.13 μg/g of BAANTR at RPS-91-40. In the West Rocket Paste Area, polynuclear aromatic hydrocarbons were detected in 10 of 28 samples with a maximum of 0.223 μg/g PYR in RPS-91-23.

Phthalates detected at the Rocket Paste Area include B2EHP and DEP. B2EHP was detected in only two samples in the Rocket Paste Area, RPS-91-11 (1.56 μg/g) and RPS-91-21 (1.61 μg/g). In the East Rocket Paste Area, DEP was detected in 14 of 38 samples. Seven of these samples had concentrations greater than 6.2 μg/g. In the West Rocket Paste Area, DEP was detected in 19 of 26 samples with a maximum concentration of 49.8 μg/g. Ten of the samples in the West Rocket Paste Area had DEP concentrations greater than 6.2 μg/g. However, at two of these 10 sample locations, DEP was also detected by another laboratory analytical method at concentrations of 47.1 to 49.8 μg/g (see Appendices K and L).

NNDPA was the dominant nitrosamine detected and was also the most predominant contaminant detected in surface soils. However, in many samples, particularly in the West Rocket Paste Area, concentrations were relatively low (less than 3 μg/g). The nitrosamines NNDNPA and NNDMEA were also detected. However, these compounds were only detected at locations where NNDPA was also detected and in all cases had concentrations at least 100 times lower than the NNDPA values. Given this condition, all nitrosamine analyses are discussed in the context of the NNDPA concentrations. NNDPA distributions between the East and West Rocket Paste Areas are illustrated in Figure 8-8 and differ as follows:

- In the East Rocket Paste Area, NNDPA was detected in 36 of 38 samples with concentrations ranging from 0.092 to 10,000 μg/g.

- The highest NNDPA concentration, those in excess of 1,000 µg/g, were detected in samples collected in the central portion of the East Rocket Paste Area at sample locations RPS-91-40, 50, and 51. These locations also had elevated concentrations of several other contaminants. Nineteen of the 36 samples with NNDPA detects had concentrations below 3.92 µg/g.

- In the West Rocket Paste Area, NNDPA was detected in 22 of 26 samples with concentrations ranging from 0.101 to 81 µg/g. However, with the exception of RPS-91-27 (36 µg/g) and RPS-91-34 (81 µg/g), all other detected concentrations of NNDPA in the West Rocket Paste Area were less than 3.7 µg/g.

NG was detected in the majority of samples collected from both the East and West Rocket Paste Areas. Again, the higher concentrations were detected in samples collected in the East Rocket Paste Area. Specific distributions are illustrated in Figure 8-5 and are characterized as follows:

- In the East Rocket Paste Area, 23 of the 38 samples had detectable concentrations of NG. Of the 23 samples with detects, 13 had concentrations less than 10 µg/g, four were between 20 and 50 µg/g, and six were between 130 and 1,500 µg/g. All samples with concentrations over 130 µg/g were again located in the central portion of the East Rocket Paste Area. Samples RPS-91-40 and 51 again had particularly high concentrations at 1,400 and 1,500 µg/g, respectively.

- In the West Rocket Paste Area, 19 of 26 samples had detectable concentrations of NG. Of the 19 samples with detects, 14 had concentrations below 10 µg/g, while five samples were between 10 and 50 µg/g. Samples with NG levels over 10 µg/g were scattered throughout the West Rocket Paste Area.

DNT distributions in the East and West Rocket Paste Areas are illustrated in Figure 8-9. DNTs (24DNT and 26DNT) were detected in 12 of the 38 samples in the East Rocket Paste Area. 24DNT was detected at higher concentrations than 26DNT; 24DNT concentrations ranged from 3.15 to 810 µg/g, while 26DNT concentrations ranged from 0.783 to 32.5 µg/g. 26DNT was detected at the same sample locations as 24DNT, although the 26DNT concentrations were typically 5 to 15 times lower than the 24DNT sample concentrations. As such, this discussion focuses on the 24DNT distribution. Samples RPS-91-40 and 50 (560 and 810 μg/g, respectively) in the central portion of the East Rocket Paste Area had the highest DNT concentrations. Four other samples, RPS-91-12, 38, 39, and 51, had concentrations between 24 and 93 μg/g and were also located in the central portion of the East Rocket Paste Area. The remaining six samples with detectable DNT had concentrations less than 10 μg/g and were scattered throughout the East Rocket Paste Area. At RPS-91-13, 38, and 39, DNT concentrations exceeded the calibration range of the instrument and values are reported as greater than 6.2 μg/g. At the two samples where detected 24DNT concentrations were the lowest (less than 3.95 μg/g), 26DNT was not detected. DNTs were not detected in any of the samples from the West Rocket Paste Area.

PB was the only metal consistently detected at concentrations above the site-specific and regional background concentrations of 10 to 30 μg/g. Although 16 samples in the East Rocket Paste Area and four samples in the West Rocket Paste Area had PB concentrations between 30 and 100 μg/g, their distribution is sporadic at these concentrations. PB distributions in the East and West Rocket Paste Area are illustrated in Figure 8-7 and can be summarized as follows:

- In the East Rocket Paste Area 11 of the 38 samples had PB concentrations detected at 100 to 2,200 μg/g. As with NNDPA, the highest concentration of PB occurred at RPS-91-40 (2,200 μg/g). The majority of other samples with PB above 100 μg/g also occurred in the central portion of the East Rocket Paste Area. The exception to this trend occurred at RPS-91-11, where PB was detected at 1,100 μg/g. RPS-91-11 is located at the north end of the East Rocket Paste Area next to the breaker and blend house facility, effluent drainage from this facility could have resulted in the high PB levels in this area.

- In the West Rocket Paste Area, PB was detected in 14 of 26 samples with a concentration range of 110 to 3,500 μg/g. The highest PB concentration occurred in samples RPS-91-04 (3,500 μg/g) in the ditch which leads from the Rocket Paste Pond south through the Rocket Paste Area, and in RPS-91-18 (1,400 μg/g) in the central portion of the portion of the West Rocket Paste Area. Except for samples RPS-91-23 and 30 (580 and 730 μg/g, respectively, both located in the central portion of the West Rocket Paste Area), all other elevated PB results had concentrations between 100 and 200 μg/g.

CR was detected above background (60 μg/g) in one sample (RPS-91-40 at 109 μg/g). As outlined above, RPS-91-40 has an elevated level of several other analytes.

Other metals detected in surface soil samples from the Rocket Paste ditches include HG and CR. HG was detected above background levels (0.5 μg/g) in two samples (RPS-91-15 and 40 at 0.56 and 0.716 μg/g, respectively). RPS-91-15 is located in a low area within the main drainage ditch for the East Rocket Paste Area. This sample did not have any other substantially elevated analytes of concern.

In the Rocket Paste Pond/Rocket Paste Area, 68 surface soil samples were analyzed for metals leaching capacity using TCLP. A summary of the TCLP analytical results for CD, CR, HG, and PB is presented in Table 8-12. The sample locations are shown in Figure 8-1. These tests were conducted to evaluate the leaching or migration potential for AG, BA, CD, CR, SE, HG, and PB in the surface soil at sample locations RPS-90-01 through RPS-90-16 and CD, CR, HG, and PB in the surface soils at RPS-91-17 to RPS-91-68. Surface soil sample locations RPS-90-01 through RPS-90-16 are equivalent to locations RPS-91-01 through RPS-91-16 in Figure 8-1. These analyses were conducted to determine if the surface soils at these locations would be characterized as a hazardous waste because of their high leachable metals toxicity characteristic. Only PB was detected above the Regulatory Level of 5,000 μg/ℓ in any of the surface soil samples collected from the Rocket Paste Pond/Rocket Paste Area (Figure 8-10). One location is in the ditch south of the Rocket Paste Pond and one location is a ditch in the West Rocket Paste Area.

Other locations in the Rocket Paste Pond and the East and West Rocket Paste areas had detectable TCLP values for PB that were below but very near the regulatory level. Other metals tested for TCLP were detected at a number of locations throughout the Rocket Paste Pond/Rocket Paste Area but the concentrations were well below any TCLP regulatory level.

8.4.2.2 Surface Water. During production periods, the Nitroglycerine and Rocket Paste ponds functioned as settling and or detention basins, receiving process and wash water from facilities within the Rocket Paste and Nitroglycerine manufacturing areas. Discharge water from the ponds flowed through the main drainage ditch within the West Rocket Paste Area.

Two surface water samples were collected from each of the Nitroglycerine and the Rocket Paste ponds and analyzed for TAL metals, VOCs, SVOCs, DNTs, NG, and a variety of indicator parameters (Table 8-10).

In the two Nitroglycerine Pond surface water samples, AS was detected at 4.98 and 5.43 μg/ℓ, HG was detected at 0.324 and 0.325 μg/ℓ and PB was detected at 41.2 and 45.9 μg/ℓ.

In the two Rocket Paste Pond surface water samples, PB was detected at 910 and 3,100 μg/ℓ and CR was detected at 59.5 μg/ℓ in one sample. Surface water samples from the Nitroglycerine Pond also contained AS at concentrations of 8.6 and 15 μg/ℓ.

Interpretations: Nitroglycerine Pond. The primary contaminants detected in the Nitroglycerine Pond sediments were NG, PB, and HG. NG is a component of the paste. The NG was manufactured by a batch process in PB tanks. PB likely originated in the tanks. The HG would be expected because elemental HG was used during the purity testing of NG. Laboratory wastes containing HG from plant activities may have reached the Nitroglycerine Pond and sorbed to the sediments. HG appears bound to the sediment within the pond as it is not detected at NPS-91-10. However, HG was detected in a TCLP extract sample collected at NPS-89-01 located near NPS-91-01. NG and PB are found at concentrations in the ditch greater than those detected within the pond sediments, indicating that these contaminants could have been partially flushed from the pond. PB concentrations in surface water could reflect partitioning of the PB in sediments.

Interpretations: Rocket Paste Pond. PB was the major contaminant in the Rocket Paste Pond sediments and soils of the main drainage ditch downgradient from the pond. This agrees with the results reported in the MEP (Tsai et al., 1988). PB contamination is most likely caused by the use of PB as a component of rocket paste. Concentrations above background for CR and HG and concentrations of DEP, NG, NIT, NNDPA, and SO4 were detected in the sediment and surface soil. All these materials can be attributed to the chemical compounds used in the rocket paste manufacturing operation. During propellant manufacturing operations, waste propellant in the form of an orange paste accumulated in the Rocket Paste Pond and in the main drainage ditch. In the mid- to late 1970s, sediments were removed as the facility was deactivated. However, some PB contamination still remains. A number of metals detected in the surface water from the Rocket Paste Pond are higher than background concentrations.

Interpretations: Rocket Paste Area. High concentrations of PB in surface soils were detected throughout the Rocket Paste Area drainage ditches. DNT, NG, NNDPA, and HG were also detected in the Rocket Paste Area, with the higher concentrations detected in the Eastern Rocket Paste Area. DNT was detected only in the Eastern Rocket Paste Area. During deactivation of the BAAP facility, the West Rocket Paste ditches were reportedly excavated. However, records of excavation in the East Rocket Paste Ditches have not been identified. This is in general agreement with the higher concentrations detected in the Eastern Rocket Paste Area.

The TCLP results for PB indicate that the surface soil at two locations shown in Figure 8-10, if removed, would be classified as hazardous waste. Other areas within the Rocket Paste Pond/Rocket Paste Area did not exceed the TCLP regulatory level for PB, but could represent a potential problem as a long-term source of leachable PB to groundwater.

8.4.2.3 Groundwater. The contamination assessment for the Nitroglycerine Pond, Rocket Paste Pond, Rocket Paste Area, and New Acid Area are discussed together. This is done primarily as a result of the number of groundwater wells in the area, and the low level of contamination detected in the groundwater at these locations.

Several VOCs were detected in the groundwater samples from the various locations. CH2CL2 was detected in most samples, but it was also detected in the laboratory method blanks. Therefore, its presence in samples is not considered reflective of actual groundwater quality. 13DMB, diethyl ether (DEETH), TRCLE, ACET, and MEC6H5 were all detected sporadically at low concentrations, and never in both rounds of samples from a single well. These results are not considered reflective of groundwater contamination by these compounds, as none of these VOCs were detected in concentrations or at a frequency that would indicate a significant presence in the groundwater.

SVOC analyses of the groundwater samples detected B2EHP and TRIMBZ. B2EHP was detected in three separate wells at concentrations of 32 to 145 $\mu g/\ell$. However, at each well, B2EHP was only detected during one of the two sampling rounds. In addition, the spatial distribution of the detects seems random, and does not suggest actual groundwater impact. Finally, it should be noted that B2EHP is often associated with PVC well materials. Given these observations, the B2EHP detects are not considered reflective of actual groundwater quality. TRIMBZ was detected as a tentatively identified compound in samples from two separate wells. At both wells, the TRIMBZ detects occurred in only one round of sampling. Hence, the TRIMBZ detects are not considered reflective of actual groundwater quality.

A variety of metals, anions (NIT, CL and SO4), and indicator parameters were also detected in the groundwater at several locations, some above background conditions and a few above regulatory WPAL.

As with nearly all groundwater samples at BAAP, CR was detected above the WPAL (5 μg/ℓ) in most wells during Round One. However, during Round Two, CR was only detected once, at 4.71 μg/ℓ (well S1119) which is below the WPAL and just above the certified reporting limit of 4.47 μg/ℓ. CD was also detected above the WPAL of 1 μg/ℓ in two wells during Round One (wells NAN-81-03C and NAN-81-04B), but was not detected in any of the samples collected during Round Two. PB was detected above the WPAL of 5 μg/ℓ at three groundwater monitoring wells. At two of these wells (S1119 and S1120), PB was only detected during Round Two. However, at RPM-89-02, PB was detected during both rounds at concentrations of 11.2 to 17 μg/ℓ (above the WPAL of 5 μg/ℓ). The high concentrations of PB detected in the Rocket Paste Pond and its presence in S1119 (during Round Two) suggest possible transport of PB to the water table. However, ongoing quarterly sampling of these wells, outside the USATHAMA CLASS program, by BAAP personnel have not confirmed these PB detections. Samples from RPM-89-02 have not shown detectable concentrations of PB (2 μg/ℓ certified reporting limit) in 10 samples collected between April 9, 1990 and June 3, 1992. Samples from S1119 have had only one PB detect (3 μg/ℓ) in 12 samples collected between June 29, 1989 and June 3, 1992. Two samples collected from S1120 (March 5, 1992 and June 4, 1992) have not shown detectable concentrations of PB. These results indicate there is no likely migration of PB from the Nitroglycerine and Rocket Paste Ponds and ditches to the water table in the three wells (RPM-89-02, S1119, and S1120).

Although NO3 concentrations are near background levels, 16 of the 24 monitoring wells in this area had NIT concentrations above the WPAL of 2,000 μg/ℓ in both sample rounds. Concentrations above the WES of 10,000 μg/ℓ were measured in two wells (NAN-81-02B and NAN-81-03C). These wells are located immediately downgradient of the New Acid Area. SO4 concentrations were also higher in the New Acid Area wells. At NAN-81-03C, SO4 concentrations exceeded the WPAL of 125,000 μg/ℓ with concentrations of 150,000 μg/ℓ during both sample rounds. The NO3 and SO4 results suggest that releases at the New Acid Area facility could have impacted groundwater quality. However, the impact consists of only marginal exceedances of the applicable regulatory standards. Other parameter values appear to be uniformly distributed throughout the area, indicating a slightly degraded groundwater quality.

8.4.3 Summary of Contamination Assessment

Organic chemicals such as NG, NNDPA, and DNTs were detected primarily in the Rocket Paste Pond and Rocket Paste Areas sediments and surface soils. Inorganic chemicals such as HG were detected in concentrations above background levels in the Nitroglycerine Pond, and PB was detected in concentrations above background levels in the Rocket Paste Pond and the Rocket Paste Area. PB also exceeds the TCLP Regulatory Level of 5.0 mg/ℓ in the Rocket Paste Pond, and at several locations within the Rocket Paste Area. Metals (PB, HG, and AS) detected in the surface water in the Nitroglycerine Pond were at or above the WPAL. PB and AS were detected in the surface water at the Rocket Paste Pond above the WPAL.

Groundwater samples collected throughout the area appear to contain isolated, low concentrations of several metals and anions. These parameters appear to be consistent with the site use. This includes the presence of PB above the WPAL in groundwater samples immediately downgradient of the Rocket Paste Pond, and the presence of NO3 and SO4 above the WES and WPAL, respectively downgradient of the New Acid Area.

Review of the BAAP quarterly groundwater data through September 1992 from the Nitroglycerine Pond and Rocket Paste Area and New Acid Area identify the same principal contaminants as the RI data. NIT, a compound found at levels above the WPAL and WES ubiquitously at BAAP, is also the principal contaminant at these sites.

As with the RI sample data, selected wells from the New Acid Area have concentrations of SO4 which occasionally exceed the WPAL. Within the RI sample data only well NAN-81-03C had SO4 concentrations exceeding the WPAL, although several other New Acid Area wells had concentrations above background. The BAAP quarterly sampling data, having more sample rounds per well, has shown a number of wells in this area to exceed the WPAL including NAN-81-01A, NAN-81-02B, NAN-81-03B, NAN-81-03C, NAN-81-04B and, NAN-81-04C.

PB was detected at 8 μg/ℓ (slightly above the WPAL of 5 μg/ℓ) in monitoring well S1120 during two of the three sample BAAP quarterly rounds. This is in general agreement with the RI data for this well which shows a PB concentration of 10.2 $\mu g/\ell$ during the Round Two RI sampling. PB was not detected during the Round One sampling at this well.

Downgradient of the Rocket Paste Pond PB was not detected above the WPAL at RPM-89-02 in 11 Badger quarterly sampling rounds and was detected only once above the WPAL in monitoring well S1119.

The BAAP quarterly data shows some CR and CD concentrations above WPAL with a high spike in 1989 to 1990 which has gradually decreased over time. This condition is similar to the CR detections during the RI sample rounds.

8.5 HUMAN HEALTH EVALUATION

8.5.1 Nitroglycerine Pond

The Nitroglycerine Pond and a large, low-lying area immediately east of the pond are part of the drainage system receiving runoff from the central storage and manufacturing areas of BAAP. The pond itself is small (1-1.5 acres), fenced, and typically dries up over the course of the summer. It is surrounded by pasture with some interspersed woodland, but the fencing prevents the cattle from coming into areas, where the soil is contaminated. It is described in more detail in Subsection 8.1.2.

8.5.1.1 Chemicals of Potential Concern. Chemicals of potential concern were identified for the Nitroglycerine Pond surface soil, sediment, and surface water by applying the criteria described in Subsection 4.2 to laboratory analytical results.

Complete lists of compounds detected in each media are given in Appendix O, Tables O-64 through O-66, which also show frequency of detection, ranges of detections, and rationale for exclusion. Compounds of potential concern and their respective exposure point concentrations are summarized in Table 8-13.

8.5.1.2 Human Exposure Levels. Intake levels of each chemical of potential concern were calculated for each exposed population for each relevant exposure route (i.e., oral and dermal) as described in Subsection 4.3.4. The population evaluated is the grounds maintenance worker. In addition, the future resident and future child playing at the pond were evaluated to provide a comparative exposure. This area was assumed to be unsuitable as cropland, because it is a small area that is wet for much of the growing season.

8.5.1.3 Exposure Point Concentrations. Exposure point concentrations for compounds at the Nitroglycerine Pond are taken as the maximum concentrations detected in each medium. The rationale for the use of the maximum is given in Subsection 4.3.5.

8.5.1.4 Risk Characterization. This subsection describes risk characterization at the Nitroglycerine Pond Area.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 8.6.5. Estimates of daily intake of each chemical by each route were derived as described in Subsection 4.3.4. RfD values employed are shown in Table 4-6. Detailed calculations of chemical- and route-specific HQ values are shown in Appendix O, Tables O-67 through O-70. These HQ values were summed across all chemicals and across all pathways affecting each population. The results are shown in Table 8-14. HI values are well below the target level of 1.0, indicating that the chemicals or pathways including the conservative residential scenario evaluated at the Nitroglycerine Pond pose minimal risk of noncarcinogenic health effects from chronic exposures. Although the inhalation pathway could not be fully evaluated because of the absence of RfCs for several COCs, it is not likely that the HI would increase to exceed 1.

Cancer Risks. Estimates of average daily intake were derived as described in Subsection 4.3.4. CSFs are listed in Table 4-7. Detailed calculations of intake and cancer risk estimates are given in Appendix O, Tables O-67 through O-70 and are summarized in Table 8-14. Because a CSF is not available for PB, the only carcinogenic chemical of concern at the Nitroglycerine Pond, excess lifetime cancer risk estimates could not be calculated for exposure to soil or sediment. Excess risks from ingestion and dermal exposure to pond water are estimated to be 8×10^{-8}, which falls below the target range.

Risks from PB. Because there are no dose-response values for PB, risks from this chemical were evaluated by comparing site concentrations with interim cleanup levels of 500 to 1,000 ppm (USEPA, 1989c). Lead was detected at 2,000 and 10,000 ppm in surface soil, both exceeding the USEPA cleanup range. The maximum concentration in sediment, 410 ppm, is below the cleanup level. Lead in surface soil, therefore, poses a potential risk to exposed populations.

Risks from NG. NG was detected at the Nitroglycerine Pond, but the lack of a published toxicity value prevents a quantitative evaluation of risk associated with exposure to soil contaminated with NG. NG will be discussed qualitatively in the following paragraphs. Currently, there are no toxicity values (RfDs or CSFs) identified for NG. NG has been used for the treatment of angina pectoris. Therapeutic levels may be achieved with tablets for sublingual administration containing 0.4 mg NG. A reported therapeutic dose level ranges from 2.5-5.0 mg every 2-3 hours, as needed (Poisondex, 1992). Transderm-Nitro transdermal therapeutic system is rated to release 2.5-15 mg NG over 24 hours (HSDB, 1992).

Headache, heart palpitations, nausea, vomiting, hypotension and cutaneous flushing may be sign of NG poisoning. Methemoglobinemia may result from the conversion of NG to nitrites in the body. An individual had a methemoglobin level of 7% reported following ingestion of 100 tablets of 0.4 mg NG over a 36 hour period (HSDB, 1992). Organic nitrite dependence may result from chronic exposure to NG. Withdrawal from NG may cause cardiovascular disturbances.

There is insufficient data available to accurately assess the acute sublingual or acute oral dose (HSDB, 1992). A health protective level of exposure may be developed based on the therapeutic dose of NG and using USEPA methods for developing RfDs (USEPA, 1992c).

If the lowest therapeutic level identified for an adult is 2.5 mg/day, and applying an uncertainty factor of 100 (10 for extrapolating from lowest therapeutic level, LOEL, and 10 for sensitive individuals), a proposed health protective dose level of 0.025 mg/day is developed (2.5 mg/day/100).

For oral exposure to children:

If the body weight of an adult is 70 kg, and the body weight of a child is 35 kg, then an additional safety factor of two should be applied (70 kg/35 kg).

Therefore: 0.025 mg/day/(2) = 0.013 mg/day

With a soil ingestion rate of 200 mg/day assumed for children, a health protective concentration of 65 μg/g of NG in soil was calculated for children being exposed. With a soil ingestion rate of 100 mg/day assumed for adults, a health protective level of 250 μg/g of NG in soil was calculated for adults being exposed.

The maximum concentration of NG detected in Nitroglycerine Pond surface soil is 15.8 $\mu g/g$, a concentration below the protective concentrations for either adult or child. NG was not detected in sediment. Therefore it is concluded that NG does not pose a risk to human health at the Nitroglycerine Pond.

8.5.1.5 Summary of Risks at Nitroglycerine Pond. The only chemical of potential concern detected at the Nitroglycerine Pond area is PB in the surface soil.

Based on assumed current and future human activities at this area of the BAAP site, there does not appear to be a health risk except from exposure to soil contaminated with PB. Excess cancer risk attributable to soil or sediment ingestion could not be evaluated because CSFs are not available for the chemicals of concern at this site.

8.5.2 Rocket Paste Area

The Rocket Paste Area contains a small unlined basin (the Rocket Paste Pond) and effluent ditches that conveyed storm water and liquid waste streams containing rocket paste particles during periods when the facility was operating. The Rocket Paste Pond varies in water level and dries up in some seasons. The ditches now are dry and grass covered. Approximately 10 percent of the Rocket Paste Area is paved and there are many buildings and pipelines that are part of the manufacturing facility which is now on standby status. The area, in itself several hundred acres, is bounded on the north and south by fenced pastureland to prevent cattle from grazing in built up or contaminated areas, and on the east and west by woodland. The eastern Rocket Paste Area is separately fenced. The area is described in more detail in Subsection 8.1.1.

8.5.2.1 Compounds of Potential Concern. Compounds detected in surface soil, sediment, and surface water samples from the Rocket Paste Area and Rocket Paste Pond are listed in Appendix O, Tables O-57, O-58, and O-59, along with information on frequency of detection, range of concentrations, and rationale for exclusion. Although samples taken from the ditches were originally deposited as sediment, they are now treated as surface soil. Only samples taken from the sediment of the Rocket Paste Pond are evaluated here as sediment. A comprehensive list of compounds of potential concern for the three media are presented in Table 8-15.

8.5.2.2 Human Exposure Assessment. The populations evaluated for the Rocket Paste Area is the current and future grounds maintenance worker. In addition, the hypothetical future resident and child playing in and around the pond are evaluated to provide a conservative risk number for comparison. Equations and parameter values used in calculating intake are presented in Subsection 4.3.4. Because the contaminated area consists of narrow strips of level ground between ditches, it is assumed to be unsuitable as cropland, so a farming scenario will not be evaluated.

8.5.2.3 Exposure Point Concentrations. Exposure point concentrations for compounds of concern in the Rocket Paste Area, pond, and ditches are maximum detected concentrations, according to the rationale described in Subsection 4.3.5. The exposure point concentrations are listed in Table 8-15.

8.5.2.4 Risk Characterization. This subsection describes the risk characterization.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3.4. RfD values employed are shown in Table 4-6. Detailed calculations of chemical- and route-specific HQ values are shown in Appendix O, Tables O-60 through O-63. The inhalation pathway could not be evaluated because RfCs were not available for the COCs. The other HQ values were summed across all chemicals and across all pathways including the conservative residential scenario affecting each population. The results are shown in Table 8-16. As shown in the table, HI values for all pathways with the exception of the residential scenario do not exceed a value of 1.0, indicating that these pathways evaluated at the Rocket Paste Area pose a minimal risk of noncarcinogenic health effects from chronic exposures. The HI calculated for the conservative residential scenario is 6.0, due entirely to exposure to 24DNT.

Cancer Risks. Excess lifetime cancer risks were evaluated as described in Subsection 4.5. Estimates of lifetime average daily intake were derived as described in Subsection 4.3.4. CSFs employed are shown in Table 4-7. Detailed calculations of chemical- and route-specific cancer risk estimates are presented in Appendix O, Tables O-60 through O-63.

The results are shown in Table 8-16. Estimated total excess cancer risk for a hypothetical child playing on the site in the future is $2x10^{-7}$, which is below the target range. The estimated risk of $2x10^{-5}$ to a current grounds maintenance worker falls within the target range. The estimated excess cancer risk for the conservative hypothetical residential exposure, run for purposes of comparison, is the only risk above the target range. The contributing contaminants to the risk of $1x10^{-3}$ for the future residential exposures to surface soil are 24DNT, 26DNT, BBFANT, CHRY, NNDPA and NNDMEA.

Risks from PB. Because there are no dose-response values for PB, risks from this chemical are evaluated by comparing concentrations of PB at the site with the interim cleanup level of 500 to 1000 ppm (USEPA, 1989c). In the surface soil, the maximum value detected was 3500 ppm. Lead was detected at 2,600 and 1,100 ppm in the two sediment samples, both exceeding the interim cleanup level. Therefore, PB levels are sufficiently high to pose a potential risk for exposed populations.

Evaluation of Risks from NG. NG was detected in surface soil at the Rocket Paste area at concentrations ranging from 0.709 μg/g to 1500 μg/g and in the sediment sample from the Rocket Paste Pond at a concentration of 1.76 μg/g.

Currently, there are no published toxicity values available for NG to use in quantitative risk calculations. A qualitative discussion of NG follows. NG has been used for the treatment of angina pectoris. Therapeutic levels may be achieved with tablets for sublingual administration containing 0.4 mg NG. A reported therapeutic dose level ranges from 2.5-5.0 mg every 2-3 hours, as needed (Poisondex, 1992). Transderm-Nitro transdermal therapeutic system is rated to release 2.5-15 mg NG over 24 hours (HSDB, 1992).

Headache, heart palpitations, nausea, vomiting, hypotension and cutaneous flushing may be signs of NG poisoning. Methemoglobinemia may result from the conversion of NG to nitrites in the body. An individual had a methemoglobin level of 7% reported following ingestion of 100 tablets of 0.4 mg NG over a 36 hour period (HSDB, 1992). Organic nitrite dependence may result from chronic exposure to NG. Withdrawal from NG may cause cardiovascular disturbances.

There is insufficient data available to accurately assess the acute sublingual or acute oral dose (HSDB, 1992). A health protective level of exposure may be developed based on the therapeutic dose of NG and using USEPA methods for developing RfDs (USEPA, 1992c).

If the lowest therapeutic level identified for an adult is 2.5 mg/day, and applying an uncertainty factor of 100 (10 for extrapolating from lowest therapeutic level, LOEL, and 10 for sensitive individuals), a proposed health protective dose level of 0.025 mg/day is developed (2.5 mg/day/100).

For oral exposure to children:

If the body weight of an adult is 70 kg, and the body weight of a child is 35 kg, then an additional safety factor of two should be applied (70 kg/ 35 kg).

Therefore: 0.025 mg/day/(2) = 0.013 mg/day

With a soil ingestion rate of 200 mg/day assumed for children, a health protective concentration of 65 μg/g of NG in soil was calculated for children being exposed. With a soil ingestion orate of 100 mg/day assumed for adults, a health protective level of 250 μg/g of NG in soil was calculated for adults being exposed. The detected concentration of 1.76 μg/g in sediment is lower than the estimated safe concentration developed above indicating minimal risk associated with exposure to sediment at the Rocket Paste Pond. Maximum levels of NG in surface soil exceed this safe concentration and indicate potential risk associated with ingestion of soil.

8.5.2.5 Summary of Risk at the Rocket Paste Area. Based on assumed current and future human activities at the Rocket Paste Area, the noncarcinogenic health risks are below the USEPA target level with the exception of hypothetical future residential exposure to 24DNT in surface soil. PB in the surface soil and sediment exceeds interim cleanup levels. An evaluation of NG based on the literature indicates a potential risk associated with ingestion of surface soil. An excess cancer risk above the USEPA target range was calculated for hypothetical future residents' exposure to surface soil. Nearly 86 percent of the excess risk for this conservative scenario results from incidental ingestion of soil contaminated with 24DNT, with the remainder of the risk contributed by 26DNT, BBFANT, CHRY, NNDPA, and NNDMEA. In addition, risk may be associated with concentrations of NG in surface soil although the magnitude of these risks cannot be quantified.

8.5.3 New Acid Area

The New Acid Area is in the north-central portion of the BAAP site. It consists of three acid process plants built in 1973/1974. An associated wastewater lagoon was closed and capped per WDNR Regulations in 1986.

Only groundwater was sampled at the New Acid Area, and those results are discussed in conjunction with groundwater results from the Rocket Paste Area and Nitroglycerine Ponds in Subsection 8.4.2.3.

8.5.4 Evaluation of Groundwater Quality

An analysis of the nature and extent of contamination in the groundwater associated with these three sites is presented in Subsection 8.4.3. Contaminants of potential concern are summarized in Table 8-17. In addition to frequency of detection and range of detected concentrations, federal and state standards are listed. NIT, with a maximum concentration of 11,000 $\mu g/\ell$ slightly exceeds the MCL and WES; however, its presence reflects region-wide agricultural practices, and is not the result of BAAP activities. Concentrations of CHCL3, CR, PB, CD, and TRCLE exceed WPALs, but are below federal and state standards. NA exceeds a federal reporting level.

8.5.5 Discussion of Uncertainties

Uncertainties associated with the risk assessment process are described in Subsection 5.6. A particular uncertainty in this area in the presence of NG as a COC. Because it lacks published toxicity values, it is evaluated by comparison to therapeutic doses. The effect of this estimation on the quantification of risk is unknown. Toxicity values for inhalation are unavailable for determining inhalation risks, which are consequently underestimated.

8.5.6 Summary

PB levels in surface soil and sediment at the Rocket Paste Area exceed the interim cleanup range of 500 to 1,000 ppm. Concentrations of NG in surface soil exceed a safe concentration developed from the literature. There are no estimated noncarcinogenic risks associated with exposure to surface soil or sediments for current workers or future children playing. An HI of 6.0 for future residents exposed to 24DNT in surface soil exceeds the target level of 1.0. Exposure of future residents to 24DNT, 26DNT, BBFANT, CHRY, NNDPA, and NNDMEA in surface soil produces an excess cancer risk of $1x10^{-3}$ which is above the USEPA target range, but none of the realistic exposures produce risks above the target range.

Maximum PB levels of 10,000 ppm in the Nitroglycerine Pond surface soil exceed the interim cleanup level of 500 to 1,000 ppm. There were no estimated noncarcinogenic risks associated with exposure to surface soil or sediment. Carcinogenic risks for surface soil and sediment were not evaluated because a CSF was not available for PB. The carcinogenic risk for surface water was below the USEPA target range.

8.6 BASELINE ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment for BAAP is to describe sensitive habitats and natural resource areas throughout the study area, focusing on the ecological communities at each BAAP site under investigation. In addition, baseline ecological effects associated with exposure to chemical constituents in environmental media at the facility are defined. The ecological assessment, conducted according to procedures outlined by USEPA, contains the following elements (USEPA, 1989a):

- Basewide Ecological Resource Areas (Subsection 2.2.6)
- Site Biological Characterizations (Subsection 8.6.1)
- Selection of Chemicals of Concern (Subsection 8.6.2)
- Ecological Risk Characterization (Subsection 8.6.3)

The general approach used to characterize ecological risk in this Baseline Ecological Assessment is summarized in Subsection 5.0.

8.6.1 Site Biological Characterizations

8.6.1.1 Nitroglycerine Pond. The Nitroglycerine Pond is a small (1 to 1.5 acre) pond in an area classified as a plant facility tract. In addition to the main pond, there is a large, low-lying area immediately east of the pond that historically received overflow during periods of heavy rainfall. At present, the water level in the pond and adjacent areas is low to nonexistent, and few aquatic receptors are associated with the site. Consequently, the flora and fauna associated with the Nitroglycerine Pond are similar to those described above for the Deterrent Burning Ground. ABB-ES field personnel have noted that cows congregate in the low-lying area adjacent to the pond, apparently preferring the shade offered by the surrounding tree canopy.

Reasonable exposure pathways are expected to be similar to those described in Subsection 8.6.1.2 for the Rocket Paste Area. The aquatic communities associated with both sites are currently not well developed, but could become so should the base return to active status.

8.6.1.2 Rocket Paste Area. The Rocket Paste Area comprises several hundred acres of an area classified as an agricultural land tract. In addition to the Rocket Paste Pond, a series of unlined ditches was constructed to convey storm water and process wastewater from the production facilities to either a settling basin in the

Nitroglycerine Production Area, or through the Magazine Area into the effluent drainage system discharging, historically, into Settling Pond 3 near the southern border of the plant (Hellewell and Mattei, 1983).

Approximately 10 percent of the Rocket Paste Area is paved or contains manufacturing facilities. Vegetation associated with the site includes red pine (*Pinus resinosa*), hickories, cedar (*Thuja occidentalis*), and American elm (*Ulmus americana*). Grasses and weedy herbs predominate in mowed areas and in waste areas associated with the buildings and pipeline supporting structures. This vegetation represents a valuable food resource to small mammals and bird species. While the plant is under standby conditions, few aquatic receptors are expected to occur in this area.

Terrestrial receptors could be exposed to contamination in surface soil and exposed sediments in the vicinity of the pond via direct contact and by consuming food items that have accumulated soil constituents; in addition, consumption of drinking water and contaminated prey items (plants, invertebrates, and amphibians) from the pond could result in exposures to semiterrestrial organisms. Aquatic life that occurs in the Nitroglycerine Pond can be exposed directly or by food-chain transfer to constituents both in surface water and sediment.

8.6.1.3 New Acid Area. The New Acid Area, located in the north-central portion of BAAP, consists of a complex of buildings, and a seepage lagoon area. There is minimal ecological habitat available at the site with vegetation limited to various grass and annual weedy herbaceous species, such as various mustards (*Lepidium* spp.), cocklebur (*Xanthium* sp.), and Queen Anne's lace (*Daucus carota*). Because of the nature of the habitat and the isolation from wooded areas, the only fauna expected to occur in the general vicinity of these two sites are seed-foraging birds and small rodents, such as the house mouse (*Mus musculus*) and deer mouse (*Peromyscus maniculatus*). Nonetheless, the site is not anticipated to be a preferred habitat for any foraging terrestrial receptors because of the lack of vegetation, the poorly developed soil, invertebrate fauna in the barren soil associated with the site, and the frequent human activity in this section of BAAP.

8.6.2 Selection of Chemicals of Concern

8.6.2.1 Nitroglycerine Pond. COCs chosen for surface water include AL, AS, BA, CL, PB, MN, HG, SO4, V, and NH3N2; sediment COCs include NH3, CR, PB, and HG (Table 8-18). However, few aquatic organisms exist in the Nitroglycerine Pond because of the lack of standing water throughout the year. Consequently, the potential for exposure by aquatic biota, should BAAP become reactivated in the future, was emphasized in this assessment.

The analytical data for surface soil are summarized in Table 8-18; COCs chosen include HG, NG, NH3, and PB.

8.6.2.2 Rocket Paste Area. A summary of the surface soil data used in evaluating exposure to ecological receptors is presented in Table 8-19. Following the protocol described in Section 5.0, the following constituents were chosen as COCs for the Rocket Paste Area: 24DNT, 26DNT, BAANTR, CHRY, CR, DEP, FANT, HG, NG, NIT, NNDMEA, n-nitrosodi-n-propylamine (NNDNPA), NNDPA, PB, PHANTR, PYR, and SO4.

Because the lack of aquatic receptors in the Rocket Paste Pond under current operating conditions, site-related impacts from the presence of PB in surface water was evaluated to consider future exposure, in the event that BAAP returns to active status. Table 8-19 presents the selected surface water COCs for this area, including: AL, AS, BA, BE, CL, CR, CU, iron (FE), PB, MN, NI, NIT, SO4, vanadium (V), ZN, and ammonia nitrogen (NH3N2). Sediment COCs for the Rocket Paste Pond Area include: CR, DEP, NG, NIT, NNDPA, PB, and SO4 (Table 8-19).

8.6.2.3 New Acid Area. No surface soil data are available for the New Acid Area, and COCs were not developed for this site.

8.6.3 Ecological Risk Characterization

Risks to ecological receptors that may be exposed to site-related constituents of the Rocket Paste Area, the Nitroglycerine Pond, and the New Acid Area were characterized according to procedures presented in Subsection 5.5.

8.6.3.1 Nitroglycerine Pond. Table 8-20 presents a comparison of exposure point concentrations for Nitroglycerine Pond surface water and sediment with available RTVs. The concentrations of AL, PB, FE, MN, and HG detected in surface water samples at the Nitroglycerine Pond exceed their respective RTVs, and HQs for all but MN are greater than 10. These findings suggest that any aquatic receptors that occur in this habitat could be at risk from chronic exposures to these constituents. The RTV established for HG may be overly protective, however. The HG RTV is not a true toxicological benchmark, but rather is a surface water concentration not expected to result in fish tissue bioconcentrating HG in excess of the Food and Drug

Administration (FDA) fish tissue "Action Level" of 1 ppm. No toxicological impacts to fish have been reported below a tissue burden of approximately 5 ppm, however (McKim, 1976). Despite the possibly overly conservative nature of the RTVs used in this evaluation, the magnitude of the HQs suggest that components of the aquatic habitat at the Nitroglycerine Pond could be at risk. In addition, exposure point concentrations for AL and HG (3,020 and 0.325 $\mu g/\ell$, respectively) exceeded the estimated Wisconsin WDAV for these two constituents (2,940 and 0.028 $\mu g/\ell$, respectively) (Appendix Q, Table Q-19), indicating that semi-aquatic animals that forage at the pond could be impacted via the drinking water and consumption of contaminated food exposure pathways.

Sediment concentrations of PB and HG also exceed their respective sediment RTVs (Wisconsin Department of Natural Resources Sediment Quality Criteria) (Sullivan et. al. 1985) (Table 8-20). The HQ for HG is over 200 times the RTV, also suggesting that aquatic organisms are at substantial risk from direct or indirect exposures to these sediments.

Risks to terrestrial ecological receptors that could be exposed to surface soil COCs at the Nitroglycerine Pond is presented in Table 8-21. Results are comparable to those described for the Rocket Paste Area with PB exposures resulting in a projected risk of large magnitude to primary and secondary consumer species (i.e., rodents, small birds, reptiles). Chronic HIs for both the fox and hawk were less than 10 and the projected risks are within the range of greatest uncertainty.

8.6.3.2 Rocket Paste Area. Surface water samples collected from the Rocket Paste Area Pond contained many analytes that exceed respective surface water RTVs, including the following: AL, CR, CU, FE, PB, MN, and ZN (Table 8-22). Most notably, HQs for AL and PB were 41.9 and 970, respectively. The RTV for copper is based on the estimated WDAV, but the USEPA AWQC and the Wisconsin WQC for this inorganic compound were exceeded as well (Appendix Q, Table Q-17), suggesting that both aquatic and semi-aquatic birds and mammals could be impacted during drinking and foraging activities at the Rocket Paste Area Pond. Although the RTVs for CR, MN, and ZN were all below 10, they could be contributing to the overall risks at the pond; assuming additivity, an HI of over 1,000 is obtained.

Sediment samples collected from the Rocket Paste Pond Area contained one analyte, PB, which exceeded its respective sediment RTV (based on the WDNR Sediment Quality Criteria) (Table 8-22). The estimated HQ is 52, which represents a significant degree of risk to benthic infauna in the pond.

Risk to terrestrial receptors that could be exposed to surface soil COCs at the Rocket Paste Area was estimated by modeling exposures associated with the incidental ingestion of soil and the consumption of contaminated prey items. Acute and chronic HIs for all indicator species were greater than 10, suggesting most terrestrial organisms, even wide-ranging predatory species, that forage at the site could be impacted (Table 8-23). The PB exposure dosage for the shrew (and other similar small mammals) is estimated to be more than five orders of magnitude higher than concentrations shown to reduce rodent fecundity under laboratory conditions. Although HI values for the other indicator species were substantially less than those estimated for rodents, impacts are likely to occur at these trophic levels as well.

PB accounted for nearly all the projected risk to small mammals, small birds, and reptiles (Appendix R, Tables R-54 and R-55); individual HQs for PB, 24DNT, and NG were responsible for over 90 percent of the total acute and chronic HIs for the fox, and NNDPA (and HG for chronic exposures) were significant risk contributors to the indicator hawk species.

8.6.3.3 New Acid Area. A quantitative risk characterization was not conducted for the New Acid Area site because of a lack of surface soil data. However, as discussed in Subsection 8.6.2.2, it is not likely that this area will be regularly utilized by ecological receptors because (1) it is located in an active part of BAAP, (2) there is minimal natural vegetation in the vicinity, and (3) the available habitat provides little cover or food resources.

8.6.4 Ecological Risk Assessment Conclusions

8.6.4.1 Effects on Aquatic Receptors. Aquatic and semi-aquatic birds and mammals were found to be at risk from exposure to AL, CU, and PB contamination in the Rocket Paste Pond surface water; CR, MN, and ZN may also be contributing to the overall risk experienced by aquatic inhabitants of the pond. Exposure to PB, HG, FE, AL, and MN in Nitroglycerine Pond surface water may be impacting aquatic organisms and the estimated WDAVs for AL and HG were exceeded as well. Benthic organisms in the Rocket Paste Pond and the Nitroglycerine Pond were found to be at significant risk due to exposure to PB and HG (Nitroglycerine Pond only) in sediments at these two areas. It is important to point out that these risk estimates are based on **maximum** detected analyte concentrations; more typical exposure levels may be considerably lower as a result.

8.6.4.2 Effects to Terrestrial Receptors. Most terrestrial receptors, including wide-ranging predatory species, at the Rocket Paste Area are likely to be impacted by the surface soil contaminants PB, 24DNT, and NNDPA. Small animals, such as the short-tailed shrew, small birds, and reptiles, are at the most risk from exposure to PB. The indicator hawk and fox species appear to be at most risk from PB, 24DNT, and NNDPA at Rocket Paste Area. PB exposures in surface soil and the Nitroglycerine Pond projected the highest risk in primary and secondary consumers.

Risks to ecological receptors were projected for PB and HG surface soil concentrations within the range of naturally occurring background levels. This suggests that the computer models used to characterize exposure levels and risks may be overly conservative. Although the approach taken is warranted in a baseline assessment where the occurrence of sensitive and protected species has not been ruled out, impacts on the ecological community found at these areas may be considerably less likely than indicated. Field studies to quantify actual exposure concentrations (e.g., biological tissue analysis) and toxicological effects (e.g., soil bioassays) would provide more accurate information on risk model assumptions. In addition, these risk conclusions should be reevaluated following the survey of flora and fauna at BAAP to be conducted in 1993. A less conservative approach to evaluating toxicological effects, focusing on potential population-level impacts rather than impacts on individual organisms, may be warranted if no species of special concern are noted in the Nature Conservancy survey.

Although a quantitative risk evaluation was not conducted for the New Acid Area because of the lack of surface soil data necessary to evaluate the magnitude of ecological exposures, it is unlikely that this area will be regularly utilized by the majority of species given the overall poor habitat quality and frequent human activity in the area.

8.7 CONCLUSIONS OF THE BASELINE HUMAN HEALTH AND ECOLOGICAL ASSESSMENTS

8.7.1 Nitroglycerine Pond

The human health evaluation identifies a need to develop a remedial response objective in the FS to reduce exposure to or concentrations of PB in surface soil.

The ecological assessment indicates that the FS should address reduction of exposure to, or concentrations of, PB, HG, and NG in surface soil; CR, HG, and PB in sediment; and AL, FE, HG, MN, and PB in surface water.

8.7.2 Rocket Paste Area

Based on human health risks, the FS should address reduction of exposure to or concentrations of PB and NG in surface soil and sediment.

The ecological evaluation indicates a need to develop remedial action objectives to reduce exposure to, or concentrations of, 24DNT, 26DNT, NNDPA, PB, CR, HG, and NG in surface soil; PB and CR in sediment; and AL, CR, CU, FE, MN, PB, and ZN in surface water.

8.7.3 New Acid Area

Only groundwater was sampled at the New Acid Area: it is included in the conclusions regarding groundwater beneath these three associated sites.

8.7.4 Groundwater

The human health evaluation indicates that remedial action objectives are not warranted for groundwater beneath the Rocket Paste, Nitroglycerine Pond, and New Acid Areas.

9.0 OLEUM PLANT, OLEUM PLANT POND, AND BALLISTICS POND

9.1 PAST DISPOSAL PRACTICES

The Oleum Plant, Oleum Plant Pond, and Ballistics Pond are located near the northern boundary of BAAP (Figures 1-2 and 9-1). Since these sites share similar geologic and disposal practices; they are described together in this section.

<u>Oleum Plant and Oleum Plant Pond</u>. The Oleum Plant was created during 1942 to 1945. Production also occurred from 1951 to 1956, and from 1967 to 1975. The plant was closed in 1975 shortly before the start-up of the new sulfuric acid facility in 1976 (Tsai et al., 1988). Along with the Oleum Plant facilities, this site includes a sulfur storage area at the western end of the plant, and a low-lying area north of the concrete storage pad. Traces of elemental sulfur are visible on the ground in former storage areas next to and south and west of the Oleum Plant. This agrees with observations in a 1981 report, which noted that in one small low lying area (i.e., less than 1 acre) elemental sulfur was distributed evenly in scattered patches (EEI, 1981).

The Oleum Plant was used to make oleum, a concentrated sulfuric acid containing dissolved sulfur trioxide. The MEP reports the production process consisted of spraying molten sulfur into a brick-lined furnace where it was burned to produce sulfur dioxide (Tsai et al., 1988). The combustion gases were cooled, filtered, and then passed over catalytic converters to generate sulfur trioxide. The resulting gases were cooled and the sulfur trioxide absorbed in water or sulfuric acid (USATHAMA, 1977).

According to the MEP, cooling water from a cascade cooler was discharged to the Oleum Plant Pond located east of the Oleum Plant during periods of operation (Tsai et al., 1988) (Figure 9-2). Soda ash (i.e., sodium carbonate) was used to neutralize the cooling water whenever leaks occurred and for other neutralization purposes (e.g., cleaning out tanks). Lime was also used to neutralize acid spills and tank overflows. Effluent from these activities was also discharged to Oleum Plant Pond. It was reported that the neutralization agent used was 80 percent soda ash and 20 percent lime (Tsai et al., 1988).

The Oleum Plant Pond is an unlined natural depression assumed to have been in operation from the early 1940s to 1975, when the Oleum Plant was closed.

Reportedly, the pond was never completely filled, even during peak use. The pond, characterized in the 1981 EEI report as being now dry, contains extensive sediments (Kearny, 1987; and EEI, 1981). These sediments are likely the result of soil erosion at the plant outfall with subsequent sedimentation into the pond.

Spills, leaks, and tank overflows at the Oleum Plant would be expected to contribute SO4 to surface and subsurface soils, as well as sediments and possibly surface water and groundwater. Metals (e.g., FE) dissolved under low pH conditions from soil, and from pipes and tanks used to store sulfuric acid, possibly were also mobilized. Historical data on locations, amounts, and dates of spills at the Oleum Plant are not available. Elemental sulfur is not expected to contribute significant SO4 to groundwater, because the oxidation rate of large pieces of elemental sulfur is quite slow. This slow oxidation rate is evidenced by the presence of remnant sulfur patches on the ground surface at this site.

Most of the neutralized acid discharged to the Oleum Plant Pond was likely in the form of dissolved sodium sulfate and calcium sulfate slurry. Because NA and SO4 ions are quite mobile and dissolve easily in water, these analytes are the principal contaminants of concern at this site.

The following information regarding facility operation has been gathered from a review of aerial photographs dated from 1944 to 1978. The 1949 aerial photographs indicate that discharge from the Oleum Plant to the Oleum Plant Pond could have taken place via a surface pipe. In the 1949 photograph, a line exiting the plant ends at the head of an eroded gully leading to Oleum Plant Pond. The gully is located next to and parallel with the railroad tracks. A barren rectangular area, apparently used for sulfur storage, is also visible west of the Oleum Plant across the access road (see Figure 9-2). Surface drainage from this barren area is clearly visible.

The 1955 photographs show that an area northwest of the plant might have been used as a lagoon during this period (see Figure 9-2). This area has limited vegetation and an inflow channel to the lagoon is clearly visible at the closest point to the plant. In the 1955 photographs, the surface pipe, identified in the 1949 photographs as running to Oleum Plant Pond, does not appear. The inflow gully and an area near the lowest point of the Oleum Plant Pond depression is barren and appears to represent erosion and/or sedimentation.

The 1962 photographs show no discharge activity at either the Oleum Plant Pond or the possible lagoon area northwest of the plant. The barren area west of the facility appears to have enlarged slightly in the 1962 photograph relative to the 1955 photograph.

The 1968 photographs show the Oleum Plant Pond east of the Oleum Plant at its maximum size. The inflow point is not evident in the 1968 photographs. The barren area west of the plant, including a new rectangular area, also appears to be at maximum size in 1968. In addition, large areas of barren ground are visible in and around the facility.

The 1986 photographs show that vegetation appears to have reclaimed most of the previously identified barren areas. In the 1986 photographs, no active erosion or sedimentation is visible around the pond area. The pond is smaller than in 1968.

Ballistics Pond. The Ballistics Pond is an unlined pond approximately 5 acres in area located in the northwestern corner of BAAP (Figures 9-1 and 9-3). Ballistics Creek drains Pine Hollow in the Baraboo Hills past the Ballistics Pond, eventually flowing off the installation to the west. Aerial photographs indicate that the Ballistics Pond was created sometime between 1940 and 1944, the depression being a result of borrow excavation operations during the construction of BAAP. It also appears that during construction of BAAP in 1942, Ballistics Creek was channelized to flow north of, and around, Ballistics Pond. The actual date of this channelization could not be determined from aerial photography. According to chemical data summarized in the MEP, soils and sediments in Ballistic Creek were determined to be not hazardous. According to the MEP, the pond collected only natural drainage before 1941, and filter backwash water from the water filtration plant after 1971 (Tsai et al., 1988).

The main purpose of the pond was to serve as an evaporation and settling basin for removal of suspended solids from filter backwash water. Suspended solids in Lake Wisconsin water entering the water filtration plant were removed by treatment with cationic-polymer-type flocculants and coagulants (i.e., alum) to increase the settling rate. The water was then filtered through sand and activated carbon filter beds to remove organics and suspended solids. Backflushing of these systems was conducted periodically as part of routine maintenance. Rocket motors were test-fired at the building on the southern shore of Ballistics Pond (Figure 9-3). Static test-firing of these motors could have left residues of PB, 24DNT, 26DNT, NNDPA, NG, and NC that could have been washed into Ballistics Pond. Primary contaminants to be expected in the Ballistics Pond are AL and possibly SO4 (Tsai et al., 1988). Overflow from the pond is diverted south to the BAAP industrial sewer.

The 1949 photographic set shows the pond area. On this date, the flooded portions consisted of two small water bodies (see Figure 9-3). Surface inflow or outflow points, based on the presence of erosional scars and newly deposited material, are visible in the photographs. These appear at the northeastern, northwestern, and southeastern corners of the depression. The deposits associated with the inflow and outflow points probably represent native soil material from erosion at these points. Inflow at the northwestern corner appears to represent surface flow from the area parallel to the perimeter road north of the site. Inflow at the northeastern corner primarily comes from the east by way of a man-made channel. The southern inflow appears to represent the collection of surface water from the area around the Rocket Motor Static Testing Facility. In addition, the four storage and treatment chambers at the filtration plant appear empty in the 1949 photographs indicating that the filtration plant was likely inactive in 1949.

The 1955 photographs indicate a larger flooded area in the bottom of the depression, as well as a road along the eastern side of the pond, with at least one apparent dumping point in the gully formed by inflow at the northeastern corner. In the 1955 photograph, the four chambers at the filtration plant appear to be in use.

The 1962 photographs show that, for the most part, the road along the eastern side of the pond is not present. The water level in the pond area is lower in 1962 than in 1955, and restricted to two areas. The 1962 aerial photographs indicate that vegetation has been reestablished around the pond. In addition, only one chamber at the water filtration facility contains water.

The 1968 photographs show the ponded area at a higher level than in previous photographs, with many partially submerged trees in full foliage. No active erosion at surface inflow points is visible. In the 1968 photographic set, a barren area exists between the Rocket Motor Test Facility, and the pond, possibly indicating active rocket motor testing. In addition, the chambers at the filtration plant appear to be full of water.

The 1986 photographs show the pond's largest areal extent to date (see Figure 9-3), with none of the chambers at the filtration plant active. This is a good indication that the pond bottom has likely been plugged with flocculants and/or fine sediments (silts and clays) and that infiltration of surface water at the pond has been restricted.

9.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

The following subsections describe the field program activities and rationale. Table 9-1 summarizes the program elements. Conduct of the field program was specified in the following documents: (1) Sampling Design Plan (Data Item A004), (2) QC Plan (Data Item A006), and (3) HASP (Data Item A009).

9.2.1 Soil Borings and Subsurface Soil Sampling

Thirteen soil borings were drilled at the Oleum Plant and Oleum Plant Pond as part of the RI. Locations of the borings are illustrated in Figure 9-4. Of the 13 borings, five were deep borings and eight were shallow borings. The purpose of these borings was to collect subsurface soil samples for further characterization of the geologic environment and assessment of the nature and vertical distribution of chemicals at these sites. The borings were drilled by John Mathes Associates of St. Louis, Missouri, under subcontract to ABB-ES. The logs of soil borings are included in Appendix D. Chemical analyses are summarized in Subsection 9.2.5. Results of subsurface soil sample analysis are discussed in detail in Subsection 9.4.

Soil borings were advanced with 6.25-inch ID HSAs and, in the case of OPB-91-01, 10-inch dual-walled driven casing. Subsurface soil samples were collected with a 3-inch ID split-spoon sampler. Samples were collected at 5-foot intervals from the ground surface to 30 feet bgs. Subsequent sampling was conducted at 10-foot intervals to the bottom of the boring. Actual drilled footages, numbers of samples collected, and the purpose of the soil borings at the Oleum Plant and Oleum Plant Pond are listed in Table [illegible]. In each soil boring, analytical soil samples generally were collected at zero to 2 feet, 5 to 7 feet, 10 to 12 feet, 20 to 22 feet, and at the water table. Drilling and sampling equipment was decontaminated between samples and borings by steam-cleaning with water from Production Well No. 2.

Five deep borings, OPB-91-01 through OPB-91-05, were drilled to the water table or refusal. At the Oleum Plant, HSA refusal on boulders was encountered at OPB-91-01 at 10 to 20 feet. This boring was then completed using the 10-inch dual-walled driven casing technique to a depth of 59 feet, where bedrock was encountered above the water table. Four borings (i.e., OPB-91-02 through OPB-91-05) were drilled at the Oleum Plant Pond. OPB-91-02 was drilled near the pond influent area, extending from the ground surface to 88 feet bgs where HSA refusal on a possible glacial till was encountered. OPB-91-03 and OPB-91-04 were drilled at the pond edge, from ground surface to approximately 101 and 90 feet bgs, respectively. The water table in these borings stabilized at 92 feet bgs (OPB-91-03) and 89 feet bgs (OPB-91-04). OPB-91-05, located near the apparent high water edge of the pond, extended from ground surface to 93 feet bgs, where auger refusal was encountered. Eight shallow HSA borings (OPB-91-06 through OPB-91-13) were made in and around the Oleum Plant production facilities. The shallow borings depths were from 6 to 12 feet bgs. Table 9-2 contains details of the borings.

9.2.2 Monitoring Well Installations

Three wells were installed at the Oleum Plant and Oleum Plant Pond during the RI; locations are shown in Figure 9-4. These wells supplement two existing wells located in this vicinity. Well locations were based upon a review of subsurface conditions at the Oleum Plant and Oleum Plant Pond area. Analytical data and aerial photographs of the site were also reviewed. Based on this review, several changes were made to initial monitoring well recommended locations. Well OPM-89-01 was installed approximately 300 feet southeast of the former sulfur storage area and former lagoon. Although this was intended to be constructed as an overburden well, shallow bedrock at this location necessitated the construction of a bedrock well. In addition, two shallow wells (i.e., OPM-89-02 and OPM-89-03) were installed downgradient of the Oleum Plant and Oleum Plant Pond. These wells were approximately 600 and 1,200 feet, respectively, southeast of the pond and the plant. Table 9-3 summarizes the well information and siting rationale.

The three water table monitoring wells installed in the vicinity of the Oleum Plant and Oleum Plant Pond were completed between November 7 and 13, 1989. The wells were installed by John Mathes Associates, Inc., of St. Louis, Missouri, under subcontract to ABB-ES. Borings for the monitoring wells were advanced using 9-inch OD drill-through-casing hammer technique. Soil samples were collected and visually logged from recirculated drill cuttings.

Monitoring wells were constructed with 4-inch diameter, Schedule 80 PVC supplied by Monoflex, Inc., of Largo, Florida. Screen intervals were 20-feet long and were constructed with Schedule 80 PVC with machine-slotted 0.010-inch-wide openings. Screen intervals were positioned to straddle the water table with approximately 15 feet below and 5 feet above the water table.

Sandpacks were placed in the annular spaces between the well screens and borehole walls. The sandpacks of the water table monitoring wells generally extend 5 feet above the top of the screens. A 5-foot bentonite pellet seal was placed above the sandpack. Above the pellet seal, Type II cement/bentonite grout was placed to the ground surface. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated approximately 3 to 4 feet into the ground. A coarse 1- to 1.5-inch stone blanket (6 inches thick) was placed around each protective casing.

Well installation diagrams with associated boring logs are in Appendix D. Grout was allowed to set for a minimum of 48 hours before the wells were developed. Well development was completed with a compressed-air-operated positive displacement pump. During well development, a minimum of five well volumes were purged from each well. Well development data sheets are presented in Appendix D.

The new wells are identified with a letter prefix, OPM, where OP indicates the site (i.e., Oleum Plant) and M indicates a single monitoring well. The number 89 indicates the year the well was installed. At nested well sites the M designation is replaced with a N. Well screen designations A, B, C, and D are added to represent progressively deeper installation intervals. A well number without a letter suffix (e.g., 89-01), or a well number with an A suffix (e.g., 89-01A) represents a water table well. The B suffix (e.g., 89-01B) represents an intermediate level well, while the C and D suffixes represent progressively deeper well screen intervals.

9.2.3 Permeability Testing

To obtain an assessment of permeability variations within the unconsolidated aquifer at the site, a series of rising-head slug tests was performed on one of the new shallow monitoring wells at the Oleum Plant (OPM-89-03). Water displacement for the rising-head tests was accomplished by physical displacement of water with a cylindrical slug. The water column was depressed by displacing water with a 2-inch diameter cylinder lowered 5 to 8 feet below the static water level. After allowing the water level to recover to its static condition, the slug was quickly withdrawn, lowering the water level in the well bore. As the water rose to its static level, data was gathered for the rising-head test.

The rate of water level rise was recorded with a 20-psi pressure transducer and Hermit 2000 data logger, both supplied by In-Situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which can result in water level rebound above the static background level in settings where the hydraulic conductivity is high.

Generally, two to five tests were performed on each well to assess the variations associated with each test, evaluate any inertial effects associated with each well, and apply the maximum stress possible at each well. The test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected wells were also analyzed by the Bouwer and Rice (1976) technique (Appendix I). Results of the Bouwer and Rice analysis compared favorably with Hvorslev results. Selected tests were also analyzed by the Bouwer and Rice (1976) technique (see Appendix I). Results of the Bouwer and Rice analyses compared favorably with Hvorslev results. Results of these analyses are summarized in Section 9.3.

9.2.4 Surface Water and Sediment Sampling

During the RI field investigation, four sediment samples were collected from the Oleum Plant Pond and six sediment samples along with five surface water samples were collected from the Ballistics Pond. Appendix D contains data sheets describing the collection of each sediment and surface water sample.

9.2.4.1 Oleum Plant Pond. Four sediment samples were collected from the bottom of the Oleum Plant Pond (see Figure 9-4) to further characterize bottom sediment. No significant standing water was present in the Oleum Plant Pond at the time of sampling. Samples OPS-91-01 through OPS-91-04 were collected using a stainless steel spoon and aluminum pan. Sediments were taken from the top 1 to 4 inches, scooped into the pan, and placed in appropriate analytical bottles. Sediments consisted of fine-grained, wet, plastic silty clay. These samples were used for assessing impacts to the pond sediments.

9.2.4.2 Ballistics Pond. At the Ballistics Pond, six sediment samples and five surface water samples were collected (Figure 9-5) to further characterize bottom sediments and water quality in the pond.

Four of the sediment samples were collected along a transect that extended northeast from the former major influent point, as observed in the field and from historical aerial photographs, across the pond (BPS-91-01, BPS-91-02, BPS-91-05, and BPS-91-06). Two additional samples were collected near a possible former influent point observed in the historical aerial photographs on the western side of the pond (BPS-91-03), and on the southeastern shore of the Pond (BPS-91-04). Samples were collected with a gravity corer from the top 3 to 12 inches of sediment in the pond. Sample material was transferred to an aluminum pan with a stainless steel spoon prior to placement into appropriate sample containers. Approximately 2 to 20 feet of water was present in the Ballistics Pond at the sample locations.

Five surface water samples were also collected from the Ballistics Pond. During 1990, three samples were collected: one each from the southern, central, and eastern portions of the pond. These samples were collected from approximately 7 feet below the pond surface using a pac bomb. During 1991, two surface water samples were collected. One sample was collected near the former influent point on the northeast end of the pond. A second sample was collected near the middle of the pond. Samples were collected near the water surface directly into sample containers.

9.2.5 Groundwater Sampling

As part of the RI, ABB-ES conducted two rounds of groundwater sampling and analyses from wells in the vicinity of the Oleum Plant, Oleum Plant Pond, and Ballistics Pond. Round One was collected from November to December 1991 and Round Two was collected from April to May 1992. Table 9-4 lists the seven wells located in the Oleum Plant, Oleum Plant Pond, and Ballistics Pond vicinity sampled during the RI. Locations of the wells are presented in Figure 9-6. The specific groundwater sampling procedures are described in the BAAP RI Sampling Design Plan developed by ABB-ES, reviewed and accepted by USATHAMA, WDNR and USEPA (E.C. Jordan Co., 1989 and 1990c, ABB-ES, 1991).

Before collecting groundwater samples, the water level was measured in each well with an electronic water level meter, to the nearest 0.01 foot and well depth to the nearest 0.1 foot, and then purged. Water level data are presented in Appendix F and discussed in Subsection 9.3.3. Well depths were sounded to assess possible sedimentation within the wells.

Before sampling, the new and existing wells were purged with a submersible pump to remove stagnant water in the well casing. Purge volumes varied depending somewhat on well recharge rates. Approximately five times the estimated sandpack and well volume were purged before sampling. Purge water was monitored in the field at the time of collection for temperature, pH, and specific conductance. Variances were documented and recorded on field data sheets found in Appendix G. During the groundwater field sampling effort, equipment was decontaminated by steam-cleaning with water from Production Well No. 2.

9.2.6 Summary of Chemical Analysis Schedule

The following sections summarize the chemical analysis schedule for surface water, sediment, subsurface soil, and groundwater samples collected in the vicinity of the Oleum Plant, Oleum Plant Pond, and Ballistics Pond.

9.2.6.1 Laboratory Analytical Program. Three laboratory subcontractors participated in the BAAP analytical program: EA Laboratories of Sparks, Maryland; DataChem Laboratories of Salt Lake City, Utah; and A.D. Little of Cambridge, Massachusetts. EA and DataChem analyzed surface water, sediment, and subsurface soil samples. A.D. Little analyzed groundwater samples. Table 9-5 summarizes the surface water matrix. Table 9-6 summarizes the sediment analytical matrix. Table 9-7 summarizes the subsurface soil analytical matrix. Table 9-8 summarizes the groundwater analytical matrix.

The analytical subcontractors all use procedures consistent with the USATHAMA CLASS program for analysis of groundwater, surface water, soil, and sediment samples. Analytical methods were certified under the CLASS program for all required analytes in water and soil. Analysis of several general water quality parameters (i.e., HARD, total ALK, and TDS) did not require certification.

Chemical analytical methods are described in Subsection 4.2 of the Sampling Design Plans. Reference information on the basis of USATHAMA methodology is contained in Appendix L. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings with certified detection limits.

The analyte matrices are based on the Tsai data and the substances reportedly used in these areas (Tsai et al., 1988). The analytical program varies among the sites, depending on the suspected contaminants.

Analysis of sediment samples for sulfite was requested at the Oleum Plant Pond and the Ballistics Pond. It was recommended that SO4 analysis be substituted for sulfite for the following reasons. In soil/sediment, sulfite is generally oxidized to SO4 fairly rapidly in the presence of oxygen. It is unlikely under the environmental conditions prevailing at BAAP for substantial residual sulfite to be currently present in soils or sediments. Furthermore, there are currently no published methods for determining sulfite in soil. Methods for the determination of sulfite in waters are published in "Methods for the Chemical Analysis of Water and Waste," USEPA 377.1, and

"Standard Methods" No. 428A and No. 428B. These methods involve the titrimetric evaluation of liquid samples, and they are not applicable to soils without extensive modifications. For any method to be developed for soils, the potential for contact with oxygen in the air or soil during sample handling must be prevented or conversion of sulfite to SO4 will occur. Therefore, SO4 analysis was added to the analytical programs for the Oleum Plant Pond and Ballistics Pond as an alternative to sulfite.

At the Ballistics Pond, the primary contaminants suspected are AL and SO4. PB and NO3 were detected in previous sampling events at this site and were also assessed. CL was also added as high levels of CL ions would contribute to high chemical oxygen demand. The TOC and total organic halogens (TOX) analyses were collected as general indicators of possible organic contamination.

The Oleum Plant Pond sediments were tested for SO4 and NO3 that could have resulted from disposal of acid solutions. In addition, analyses for CA and NA were added to evaluate the effects of buffering agents (such as lime and soda ash) used to neutralize the acids before disposal.

Groundwater sampling and analysis was based on site history and previous sampling. Primary analytes were SO4 and NA at the Oleum Plant and Oleum Plant Pond. Prior groundwater sampling at the Ballistics Pond has not identified substantial contamination in the past (Tsai, 1988).

9.2.6.2 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data and geotechnical data from the field drilling program.

Appropriate field data records were completed for each groundwater, surface water, and sediment sample (see Appendices D and G). Information such as the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, and sampling technique is recorded. A field notes section provides any additional site information sampling personnel may need to include.

Where soil samples are taken from test borings, a Field Boring Log was completed. On this log, the driller and geologist record notes from the soil sampling event. Samples were given unique site IDs for sample identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data was entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both the home office and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map File, Geophysical Groundwater Stabilized File, Geophysical Field Drilling File, Geotechnical Well Construction File, Chemical Groundwater File, Chemical Surface Water File, Chemical Soil File, and Chemical Sediment File.

Chain-of-custody records along with ARFs were used to coordinate transfer of samples from field sampling locations to the laboratory. Samples were divided into sample lots according to method, matrix, and analytical QC groups.

9.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The Oleum Plant, the Oleum Plant Pond, and the Ballistics Pond are located near the northern boundary of BAAP along the flank of the Baraboo Hills. These sites share similar geologic and hydrogeologic environments.

9.3.1 Surface Water Hydrology

There is approximately 50 feet of topographic relief in the Oleum Plant and Oleum Plant Pond area, dominated by the Baraboo Hills rising abruptly to the north. The Johnstown terminal moraine transects this area with up to 25 feet of vertical relief. The Oleum Plant site area has undergone cut and fill activities associated with site construction; therefore, original site topography is not well-defined (Tsai et al., 1988).

The Oleum Plant Pond is located approximately 900 feet east of the Oleum Plant in an isolated depression. Aerial photography and visual observations made in 1989 through 1990 indicate the water level in the pond varies as precipitation, runoff, and evaporation rates change. The pond likely occupies a kettle depression left during retreat of glacial ice. The pond is perched above the regional water table. Borings OPB-91-03 and OPB-91-04, drilled next to the pond, encountered the water table at approximately 89 to 92 feet bgs.

Surface water drainage at the Oleum Plant is primarily routed to the east toward the Oleum Plant Pond, although some drainage to the northwest and west may also occur. Aerial photographs of this area taken during active site operations (i.e., 1940 to 1973) indicate process and cooling water were piped to an open drainage ditch west of the pond. The photographs also indicate a possible lagoon northwest of the plant. Regional topographic maps indicate an intermittent stream channel transecting the site, flowing from the north near the base of the Baraboo Hills toward the southwest.

The Ballistics Pond, located in the northwestern corner of BAAP, shares several characteristics with the Oleum Plant Pond. Its water level varies throughout the year, depending on precipitation, evaporation, and surface water runoff. In addition, the Ballistics Pond is perched above the regional water table, as illustrated by the water levels in wells S1127 and S1128 approximately 55 to 70 feet below the level of the pond.

Surface water drainage in the vicinity of the Ballistics Pond is principally routed through Ballistics Creek, which is a small intermittent drainage that originates in the Baraboo Hills to the north and flows north of the Ballistics Pond from east to west before discharging to Otter Creek west of BAAP.

9.3.2 Geology

Deep soil borings and monitoring wells installed in the vicinity of the Oleum Plant, Oleum Plant Pond, and Ballistics Pond have encountered variably textured unconsolidated soils on the order of 70 to more than 160 feet thick deposited in conjunction with the maximum advance of the Green Bay Lobe Glacier.

In areas undisturbed by site construction activities, the stratigraphic sequence includes a veneer of fine-grained silt and clay at the ground surface underlain by variably textured sands and gravels with occasional cobble and boulder zones that were more common in borings located closer to the Baraboo Hills (see boring logs for OPM-89-02 and S1131).

Figure 9-6 shows the locations and designations of deep soil boring and monitoring well installations at the Oleum Plant, Oleum Plant Pond, and the Ballistics Pond. Figure 9-6 also orients the geologic cross sections for this site that are illustrated in Figures 9-7, 9-8, and 9-9. The cross sections show general relationships between soil units. It is anticipated that substantial lateral and vertical variability in soil textures occur in this area.

As with other areas at BAAP, undisturbed near-surface soils are typically composed of a thin organic topsoil layer over a fine-grained loess that blankets the site. The loess unit is typically composed of windblown silts and clays with some fine sands. Where the ground surface has not been disturbed, this unit is typically 8 to 10 feet thick. However, at the Oleum Plant, the loess unit is generally absent. Construction-related activities in this area likely removed or redistributed much of the near-surface soils. Conversely, the loess unit appears to be somewhat thicker than expected near depressions such as the Oleum Plant Pond, based on boring logs for OPB-91-02 (21.5 feet thick) and OPM-89-02 (24.5 feet thick).

Borings installed in the vicinity of the plant (i.e., OPB-91-01 and OPB-91-06 through OPB-91-13 as shown on Figure 9-4) have generally encountered black-to-tan, coarse-to-fine sands with some silt and gravel and occasional cobbles near the surface. Soils are very dense with gravel and cobbles at depths of 7 to 12 feet often limiting borehole advancement. The dense, coarse soil conditions likely reflect material that has eroded off the Baraboo Hills to the north.

Below the surficial deposits, the soil texture grades from well-sorted sands and gravels to silty sands with thin silt layers above the bedrock. These soils are generally well-stratified and appear to have been deposited in a kame terrace in association with glaciofluvial and glaciolacustrine environments. However, at OPB-91-03 and 04, angular bedding in stratified soils indicated the presence of ice-contact or slump features.

Silt lenses and layers are of particular interest as they can perch infiltrating precipitation and impact the regional flow system. The silt units found west of the Johnstown terminal moraine are interpreted to have been deposited in small isolated lakes and ponds along the margin of accreting outwash stream channels in front (west) of the terminal moraine. The silts and clays found at the Deterrent Burning Ground and Existing Landfill east of the terminal moraine could have been deposited as sediment in Glacial Lake Merrimac, which occupied a basin bounded by the Johnstown Moraine and the ice front (Clayton and Attig, 1990).

Silt lenses and layers at the Oleum Plant were typically less than 1 foot thick and as such were only observed in borings sampled using a split-spoon sampler. Silt lenses usually were encountered between elevations of 825 and 835 feet MSL. Earlier work completed by Warzyn also encountered silt lenses and layers (EEI, 1981) west of the Oleum Plant and Pond. These relatively thin silt layers were identified at elevations of 830 to 840 feet MSL in boring S1129. Thin silt layers were encountered at elevations of 759 to 786 feet MSL and 804 feet MSL in borings S1127 and S1128, respectively, which are located near the Ballistics Pond. Clayton indicates the water level of Glacial Lake Merrimac was 815 to 830 feet MSL (Clayton and Attig, 1990).

Given the current geologic data regarding silt lenses at the Oleum Plant, Oleum Plant Pond, and the Ballistics Pond, it does not appear these layers are well-connected hydraulically. This hypothesis is based on the variable elevation and wide distribution of the layers across the site and their relatively thin nature. A series of small, isolated, perched groundwater zones were observed overlying the fine silt and clay layers in soil borings drilled at the Oleum Pond (see boring logs OPB-91-02, and OPB-91-03 in Appendix D).

In summary, the fine silt lenses and layers encountered along the northern portion of BAAP west of the terminal moraine were interpreted to have been deposited in small ponds and lakes along the margin of the accreting outwash streams. It is unlikely that silt layers are continuous across the northern portion of BAAP; therefore, a regional perched water table is unlikely. However, borings installed at the Oleum Plant and Pond have shown that the silt lenses and layers are capable of locally perching groundwater as it infiltrates through the soil column. Further, some of these layers could be pitched to varying degrees, reflecting ice contact slump features.

Bedrock at the Oleum Plant and Pond, as well as the Ballistics Pond, is composed of Cambrian Period sandstone with some interbedded shales underlain by Precambrian Period quartzites and quartzite conglomerates. The bedrock surface has a variable elevation, although it generally rises to the north where outcrops occur along the BAAP boundary. At S1131, the northernmost boring at BAAP, the sandstone unit is absent and a quartzite conglomerate was encountered at an approximate elevation of 865 feet MSL. At OPM-89-01, south of S1131, bedrock was encountered at an approximate elevation of 855 feet MSL. Sandstone bedrock at the Ballistics Pond was encountered in boring S1128 at an approximate elevation of 806 feet MSL, and in an abandoned background monitoring well boring BGM-91-01 at an approximate elevation of 840 feet MSL.

9.3.3 Hydrogeology of Unconsolidated Sediments

This section discusses hydrogeologic conditions along the northern boundary of BAAP at the Oleum Plant, Oleum Plant Pond, and the Ballistics Pond. This includes a summary of site conditions followed by more detailed descriptions of the major soil units, recharge rates, the presence of perched groundwater zones, bedrock conditions, horizontal gradients on the water table, and hydraulic conductivity testing. As with other sites at BAAP, hydrogeology is dominated by a highly permeable sand and gravel aquifer. However, there are two features of particular interest in the northern area. First, fine-grained silt and clay layers above the water table locally perch infiltrating groundwater above the regional water table. Second, at some areas along the northern boundary, the bedrock surface occurs above the regional water table elevation, eliminating any regional overburden aquifer that would otherwise exist in this area (see Figure 9-7).

As discussed in Subsection 9.3.2, the presence of fine-grained loess soils at the ground surface generally restricts infiltration of precipitation below the ground surface. However, at the Oleum Plant, it appears construction activities have removed or reworked much of the fine-grained soils. This is in contrast to conditions at the Oleum Plant Pond, where it appears deposits of fine-grained silts and clays are somewhat thicker in the topographic depression. Recharge rates of 5 to 7 inches per year occurs in areas where the loess unit is present. The recharge rate likely increases to approximately 7 to 9 inches per year in areas where the loess is missing and no impermeable surface such as concrete has been installed.

The ability of the fine-grained silts and clays to perch water is illustrated by the presence of the Oleum Plant Pond and Ballistics Pond, which perch water approximately 90 feet above the regional water table. However, at these locations, the local recharge rate may be higher than other portions of the site as the surface water runoff is ponded in the depressions and a significant positive potential for recharge to groundwater may exist for an extended period. As discussed in the previous subsection, the soils encountered in borings adjacent to the pond include numerous stratified sand and silt layers. Some of these fine silt layers support distinct perched water zones (see borings logs OPB-91-02 [20 feet bgs] and OPB-91-03 [9, 21 to 26, and 39 feet bgs]). Boring OPB-89-05, located approximately 150 feet farther from the pond than the other borings, also penetrated highly stratified soils. However, no distinct perching of water was observed in this boring. This suggests that perched zones are very localized to the area immediately adjacent to the pond and have limited lateral extent.

The groundwater flow along the northern BAAP boundary includes three separate conditions illustrated in the geologic cross sections (see Figures 9-7, 9-8, and 9-9). The first condition involves the overburden water table encountered at approximate elevations of 810 to 820 feet MSL at the Ballistics Pond (i.e., S1127 and S1128). These elevations are approximately 15 to 30 feet above the elevations for regional water table conditions in the aquifer in the unconsolidated sediments immediately south of this area in background monitoring wells. A review of soil conditions at these wells indicates fine-grained stratified silty sands over bedrock. The silty soil conditions and shallow bedrock surface combine to restrict downward flow of infiltrating groundwater and form an isolated shallow overburden flow system in the vicinity of the Ballistics Pond. Although wells S1127 and S1128 indicate a strong gradient from north to south, the lack of a third well in this area precludes development of a water table contour plan for this isolated system. However, it appears likely this isolated system does flow to the south and discharges into the regional overburden flow system (Figure 9-10). This condition is similar to the elevated flow system observed at the Deterrent Burning Ground and Existing Landfill (see Subsection 7.3). However, it is unlikely that these systems are hydraulically well connected across BAAP.

The second groundwater regime, along the northern BAAP boundary, consists of a bedrock flow system encountered at approximate elevations of 820 to 860 feet MSL in the vicinity of the Oleum Plant and Pond (i.e., S1129, S1130, S1131, and OPM-89-01). Overburden soils at these locations were generally unsaturated and groundwater was encountered below the bedrock surface. Groundwater elevations are approximately 30 to 80 feet above the expected regional overburden water table in this area. It appears the groundwater flow system in the bedrock is controlled by fractures (in quartzite units) and primary porosity (in sandstone units). In addition, the bedrock system has a much lower permeability than the regional sand and gravel flow system. The lower permeability in the bedrock maintains steeper horizontal and vertical gradients, thereby allowing a higher water table elevation. At well S1129, screened just below the bedrock surface, the water level appears to reflect conditions in the overburden soils where water levels are 15 to 30 feet above the regional water table. Substantial downward vertical gradients ($i=0.16$ ft/ft) have on occasion been observed at the S1130/S1131 well nest. However, these gradients appear to be transient, and are likely associated with substantial recharge events.

As Figures 9-7 and 9-10 indicate, water level elevations measured in the bedrock at S1129, S1130, and OPM-89-01 indicate irregular water levels. The shallow depth to bedrock encountered at OPM-89-01 (i.e., 860 feet MSL) results in a much higher groundwater elevation (i.e., 859.9 feet MSL) than observed in other bedrock wells. The bedrock water levels have not been contoured as adequate bedrock groundwater level data are not available to clearly distinguish the piezometric head in the bedrock. In the northern portion of BAAP, bedrock dips to the south. Groundwater in the bedrock flow system likely discharges to the south into the overburden sand and gravel water table flow system (see Figure 9-10).

The third groundwater regime along the northern BAAP boundary involves the regional overburden flow system encountered at elevations of 778.1 to 779.1 feet MSL east and south of the Oleum Plant Pond in wells S1132, OPM-89-02, and OPM-89-03. Groundwater elevations encountered in these wells correlate with the regional sand and gravel water table. However, as Figure 9-10 indicates, there is very little change in the water table elevation (approximately 1 foot) over a large lateral distance (i.e., 2,200 feet), resulting in a very small, nearly flat, horizontal gradient of 0.0004 ft/ft. In addition, fine silt and clay layers encountered at DBN-89-04A and B restrict the downward migration of infiltrating water and result in semi-confined conditions. The water levels presented in Figure 9-10 indicate groundwater flow is generally to the south and east.

Hydraulic conductivity tests were conducted at several existing monitoring wells installed at the Oleum Plant and Oleum Plant Pond. The tests consisted of in situ slug withdrawal tests performed by ABB-ES (see Subsection 9.2.3) at well OPM-89-03, and by Warzyn at wells S1130 and S1131 (EEI, 1981). The results of tests performed by ABB-ES are summarized in Table 9-9 while the raw data, graphical plots, and calculations are in Appendix F. The test at OPM-91-03 suggests a hydraulic conductivity on the order of $1x10^{-1}$ cm/sec. Tests performed by Warzyn in the bedrock wells indicate a hydraulic conductivity approximately three orders of magnitude lower than that measured in the sand and gravel wells.

In summary, groundwater flow conditions near the northern boundary of BAAP are predominantly controlled by the presence and elevation of the bedrock surface. Locally, fine sediment lenses may perch infiltrating groundwater. However, these perched zones have a small lateral extent. The water table in this area is typically elevated 10 to 60 feet above the regional water table in the overburden. It appears water slowly discharges from the bedrock flow system and likely recharges the fine-grained stratified soils. These soils support an isolated overburden flow system. Groundwater from this system in turn recharges the regional overburden flow system. The bedrock flow system along the northern site boundary should be considered separate from the sand and gravel flow system occupying most of the BAAP site.

9.3.4 Groundwater Movement

Groundwater flow at the Oleum Plant, Oleum Plant Pond, and Ballistics Pond occurs as three distinct flow systems in the overburden and bedrock along the northern BAAP boundary. As described in the previous subsection, the first flow system is an isolated overburden system occurring in and above the fine-grained stratified silty sands overlying an elevated bedrock surface. Table 9-10 indicates horizontal gradients in this area are approximately 0.008 ft/ft and could be somewhat steeper because the precise flow direction cannot be determined from existing data. The steeper gradients reflect the lower permeability of this unit.

The second flow system occurs in the bedrock. In this area, the potentiometric surface of the bedrock is irregular. Given the limited number of wells in the bedrock, a clear definition of the hydraulic gradients and flow velocities cannot be determined. However, it appears the bedrock flow system discharges to the overburden. Therefore, contaminant migration from the sand and gravel aquifer into bedrock is not anticipated.

The third flow system occurs in the thick sand and gravel overburden deposits south of the northern BAAP boundary. Table 9-10 indicates horizontal gradients in this area on the order of 0.0004 ft/ft. These flat gradients reflect the permeable nature of the aquifer in this area as well as the potential for semi-confined conditions in areas where fine-grained soils occur at the water table (i.e., the Deterrent Burning Ground).

As discussed in Subsection 7.3, the Oleum Plant and Oleum Plant Pond could be located within the capture zone of BAAP Production Well No. 4. Groundwater velocity calculations have not been performed for this area as the flow directions have not been well-defined. However, within the regional overburden aquifer, groundwater velocities are expected to be consistent with other areas within BAAP, ranging from 100 to 400 ft/yr.

9.4 NATURE AND EXTENT OF CONTAMINATION

9.4.1 Introduction

The contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in soil and groundwater at BAAP.

Chemicals that represent site-related contamination were identified based on the evaluations of soil, groundwater, and surface water sample analytical results as compared to background concentrations; frequency of occurrence and concentrations of each chemical; and the relationship of chemicals to past activities. The BAAP RI contamination assessment addresses the 11 priority SWMUs located within BAAP. This section addresses conditions at the Oleum Plant, Oleum Plant Pond, and Ballistics Pond. The primary data used in this report are the results of chemical analyses of surface water, sediment, subsurface soil, and groundwater collected at these sites since September 1990.

Data collected before January 1988 were summarized in the MEP (Tsai et al., 1988). These data contained inconsistencies because of the use of differing analytical methods, sampling techniques, and protocols. However, these data are used to augment the description of contaminant nature, distribution, and behavior.

Within each subsection, results of chemical analyses are presented by medium (e.g., surface water, sediments). Within each medium, chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). Indicator parameters are nonspecific measurements that grossly characterize water quality. The indicator parameters measured in this program were HARD, ALK, and TDS. These parameters are used, where appropriate, to assist in site-specific data interpretation. Chemical-specific numerical standards and criteria used to evaluate chemical data are listed in Table 3-3, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WESs, and WPALs. Chemical data tables downloaded from the IRDMIS are contained in Appendix K.

Appendix L details specific results of the data quality assessment. This includes: (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, (2) a listing of the USATHAMA-certified analytical methods used by the subcontractor laboratories, (3) a summary of the laboratory quality control sample results and impact on associated field sample results, (4) a summary of nontarget, library searched VOC and SVOC compounds detected in the RI analytical program, and (5) a summary of the USATHAMA-approved laboratory control charts.

The following paragraphs comprise a summary and overview of the findings of the contamination assessment. Detailed results and interpretations are contained in Subsection 9.4.2.

Oleum Plant and Oleum Plant Pond. The primary chemical identified in the Oleum Plant and Pond area was SO4, detected in the pond sediments. SO4 was also detected in soil boring samples collected from the central section of the Oleum Plant. SO4 was detected at concentrations exceeding the WPAL, but below the WES in groundwater samples collected immediately downgradient from the plant.

Ballistics Pond. Water treatment plant wastewater and sludge was disposed of at the Ballistics Pond. As a consequence of the use of alum, high concentrations of AL and SO4 were observed in the sediment. Trace levels of VOCs were also detected in the sediment and surface water samples. Analyte concentrations exceeding background values or WPALs were not detected in groundwater samples collected in the vicinity of this site.

9.4.2 Contamination Assessment

9.4.2.1 Subsurface Soil Samples - Oleum Plant and Oleum Plant Pond. Thirteen soil borings were completed in the Oleum Plant and Oleum Plant Pond areas to characterize areal and vertical distribution of contamination. Four borings (i.e., OPB-89-02 through OPB-89-05) were located adjacent to the Oleum Plant Pond and nine borings, including OPB-89-01 and OPB-89-06 through OPB-89-13, were placed around the Oleum Plant facilities. Locations of the soil borings are shown in Figure 9-4. Table 9-11 presents a summary of the subsurface chemical data for these sites. This table only lists analytes for which detectable concentrations were measured in one or more samples. Table 9-7 presents the analyses performed on each sample.

Metals and Indicator Analysis. Subsurface soil samples from borings OPB-91-01 through OPB-91-05 were analyzed for CD, CR, HG, PB, FE, NIT, SO4, TOC, and pH except at OPB-91-02 and OPB-09-03 where NI was analyzed in place of FE. Soil samples from borings OPB-91-06 and OPB-91-07 were analyzed for only NIT and SO4, and OPB-91-08 through OPB-91-13 were analyzed for SO4 only.

CR was detected at several locations in borings OPB-91-01 through OPB-91-05 above background conditions. Although the highest concentration of CR detected (30.3 μg/g at OPB-91-03 at 2 feet) is within surface background levels (23.3 to 46.8 μg/g), several of the deeper subsurface samples had CR concentrations ranging up to 28.2 μg/g, which is above the subsurface background level (1.89 to 10.4 μg/g). HG was only detected in the 2-foot sample from OPB-91-02 (0.115 μg/g), which is within the surface background conditions. PB was detected in all borings. However, only one sample exceeded the regional background concentration of 30 μg/g (OPB-91-01 at 21 feet bgs had a PB concentration of 42.0 μg/g). NI was detected in several samples collected from both OPB-91-02 and OPB-91-03 at concentrations above background conditions with the highest concentration of 23.1 μg/g detected at OPB-91-03 at 2 feet. FE was detected at all sample locations in OPB-91-01, OPB-91-04, and OPB-91-05 above subsurface background conditions, but generally below surface background conditions with the highest concentration of 43,600 μg/g detected at OPB-91-04 at 11 feet.

Inorganics. pH measurements for all samples were within background conditions (5 to 7) except at OPB-91-03 at 101 feet (12.8) and OPB-91-04 at 21 feet (13.1). SO4 exceeded background conditions in most samples with the highest concentration (14,000 μg/g) detected at OPB-91-01 at 6 feet. Figure 9-11 depicts the SO4 distribution in subsurface soils at the Oleum Plant and Pond. At borings with high SO4 concentrations (over 1,000 μg/g), the levels decreased significantly with depth, and were never greater than 20 μg/g at depths greater than 25 feet bgs. TOC concentrations ranged from 190 μg/g to 23,100 μg/g. TOC was generally higher in shallower soil samples, however, its concentration with depth did not consistently decrease. This could reflect higher organic carbon levels in the deeper fine-grained silty soil layers. With one exception, NIT levels were within background levels (1.0 to 4.07 μg/g). The single exception occurred at OPB-91-02 at 6 feet bgs where NIT was detected at 6.19 μg/g.

Interpretation. SO4 appears to be the contaminant most widely distributed at concentrations significantly higher than background. This is most likely a result of spills and other discharges from the manufacture of oleum at this location. The SO4 concentrations are generally higher in the upper 20 feet of each boring and decrease with depth. The concentrations are generally below detection levels at the water table. The SO4 detected could be a calcium sulfate salt (CASO4), formed by the reaction of oleum with the lime used to neutralize spills or other discharges. CASO4 is a stable salt. However, if the SO4 is associated with a sodium sulfate salt, formed by the reaction of oleum with soda ash, the SO4 would be more leachable.

The metals and NIT concentrations are within or near background concentrations. Concentrations above background levels could reflect the influence of the fine-grained silty nature of some of the soils encountered in this area which may promote partitioning and retard migration rates.

9.4.2.2 Sediment Samples - Oleum Plant and Oleum Plant Pond. Four sediment samples were collected from the Oleum Plant Pond and analyzed for CA, NA, NIT, SO4, TOC, and pH. The concentrations of the analytes detected are listed in Table 9-12. This table only lists analytes for which detectable concentrations were measured in one or more samples. Table 9-6 presents the analysis performed on each sample.

Metals. CA and NA were reported at concentrations within background regional sediment concentrations. The CA concentration at OPS-91-01 near the discharge inlet to the pond was nearly eight times higher than the other samples collected.

Inorganics. NIT, SO4, and pH were reported at concentrations above background as defined in Table 2-8 from analysis of samples collected from the Control Pond. No background data is available for TOC, but the TOC analytical results are consistent within the Oleum Plant Pond and are similar to subsurface soil concentrations.

NIT was detected in all sediment samples with the highest concentration being detected at OPS-91-04 at 50 $\mu g/g$. SO4 was detected in all samples with the highest concentration being detected at OPS-91-01 at 590 $\mu g/g$. pH was above background at the sample locations with the highest pH of 13.2 detected at OPS-91-01.

Interpretation. SO4 and NIT are both higher than background concentrations in the Control Pond, likely reflecting discharge from the Oleum Plant to the Oleum Plant Pond (nitric and sulfuric acids). The high concentration of CA at OPS-91-01 could be indicative of the lime used to neutralize the acids. The higher-than-background pH levels could indicate some neutralization constituents are still present in the pond sediments.

9.4.2.3 Sediment Samples - Ballistics Pond. Six sediment samples were collected from the Ballistics Pond and analyzed for VOCs, BN/As, AL, PB, NH3, NIT, and SO4. The concentrations of elements, anions, VOCs, and BN/As are listed in Table 9-12.

Organics. VOCs were not detected in any of the Ballistics Pond sediment samples. B2EHP and PHANTR were the only BN/As detected in the sediments. B2EHP was detected at BPS-91-02 and BPS-91-04 at 1.27 $\mu g/g$ and 6.1 $\mu g/g$, respectively, and PHANTR was detected at BPS-91-04 at 0.428 $\mu g/g$.

Inorganics. AL was detected at only one location above the maximum background concentration (27,300 μg/g). At BPS-91-04, the AL concentration was 58,000 μg/g. PB was detected in all samples at concentrations within the background range. NH3 was detected in all samples at concentrations within the background range. NIT was also detected at only one location (BPS-91-01) where its concentration, 5.16 μg/g, was above the maximum background range of 1.0 μg/g. SO4 was detected at all sample locations above background conditions with the lowest concentration of 62.7 μg/g at BPS-91-01, and the highest concentration at 490 μg/g at BPS-91-04.

Interpretation. The disposal of residues, mostly alum, from the water filtration facility likely resulted in AL and SO4 levels above background. The PB, B2EHP, and PHANTR are likely related to residues from the Rocket Motor Test Facility at the southern edge of the Ballistics Pond.

9.4.2.4 Surface Water - Ballistics Pond. Three surface water samples were collected from the Ballistics Pond in 1990, and analyzed for AL, CA, FE, MG, NA, PB, NIT, CL, and SO4. In 1991, two additional samples were collected from the pond and analyzed for the same parameters listed above as well as TAL metals, VOCs, and BN/As. The concentrations of the analytes detected are listed in Table 9-13. This table only lists analytes for which detectable concentrations were measured in one or more samples. Surface water background concentrations for trace metals are unavailable as no on-site background surface water samples were collected. The WDNR is currently refining its sampling and analysis techniques, and no final data have been published. Some preliminary background evaluations have been completed and are available. Therefore these are used where applicable.

Organics. No VOCs or BN/As were detected in the surface water samples.

Inorganics and Indicator Parameters. AL and PB are the principal metals of interest at this site. AL was detected within the range determined as background. However, AL and FE concentrations were higher in the 1990 samples. PB was not detected above the certified reporting limit. ZN was detected above background conditions. The other metals, anions, and indicator parameters detected were similar for the samples collected in 1990 and 1991.

Interpretation. The surface water sample analyses from the Ballistics Pond generally indicate analyte concentrations within expected ranges. No VOCs or BN/As were detected. Concentrations of AL and PB do not appear elevated. Anion concentrations for CL, NIT, and SO4 are all below WPALs and WESs. Overall, the water quality in the pond does not appear impacted by BAAP activities.

Field measured pH values ranged from 7.3 to 9.0. In-Field measured specific conductance values ranged from 76 to 204 umhos/cm. Specific conductance and pH values are within background range.

9.4.2.5 Groundwater Samples - Oleum Plant, Oleum Plant Pond, and Ballistics Pond. At the Oleum Plant and Oleum Plant Pond, there are three newly installed wells and two existing monitoring wells that were sampled as part of the groundwater monitoring program. At the Ballistics Pond, two existing wells were sampled. As shown in Figure 9-6, three additional existing wells (S1129, S1130, and S1131) are upgradient of the Oleum Plant and Oleum Plant Pond and are screened in the bedrock aquifer; these are used for background water quality data (see Subsection 2.2).

At the Oleum Plant, the newly installed wells were placed downgradient of the sulfur storage area (OPM-89-01), and the Oleum Plant facility (OPM-89-03) and the Oleum Plant Pond (OPM-89-02) to provide horizontal definition of potential groundwater impacts. Groundwater samples from these wells, and from monitoring wells S1132 and S1151, were analyzed for VOCs, CD, CR, HG, PB, CA, NA, NIT, CL, SO4, and the other indicator parameters listed in Table 9-8.

At the Ballistics Pond, the two existing wells (S1127 and S1128) were sampled as part of the groundwater monitoring program. Groundwater from these wells was analyzed for VOCs, NIT, CL, SO4, and other indicator parameters listed in Table 9-8. The analytical results from all seven wells are summarized in Table 9-14. This table only lists analytes for which detectable concentrations were measured in one or more samples.

Organics. CH2CL2 was the only VOC detected in the groundwater samples. However, this is attributed to laboratory blank contamination. No BN/As were detected in any of the samples tested.

Metals and Indicator Parameters. Of the metals analyzed for, only CA (100,000 $\mu g/\ell$ at OPM-89-01) was detected above the maximum background concentration of 86,000 $\mu g/\ell$. CR was detected above the WPAL in Round One, but was not detected during Round Two. This trend was observed in nearly all wells sampled at BAAP. Potential sources of laboratory contamination and error were investigated to explain this CR data. No sources of laboratory contamination or error were found. In addition, field records were checked and field personnel questioned; standard field sampling practices were followed during both rounds of groundwater sampling. No other metals were detected above background concentrations in either sample round.

Inorganics. NIT was detected at all sample locations during both rounds within background concentrations. CL was detected at all sample locations except OPM-89-01 during both rounds and all results were within background concentration. At OPM-89-01, CL was detected at 110,000 $\mu g/\ell$ and 130,000 $\mu g/\ell$ during Rounds One and Two, respectively. SO4 was detected within background concentrations at all sample locations except at OPM-89-01 and OPM-89-03. At OPM-89-01, SO4 was detected at 200,000 $\mu g/\ell$ and 170,000 $\mu g/\ell$ during Rounds One and Two, respectively. The CL and SO4 concentrations at OPM-89-01 are near or above the WPAL of 125,000 $\mu g/\ell$ for these analytes. At OPM-89-03, SO4 was detected at 76,000 $\mu g/\ell$ and 74,000 $\mu g/\ell$ during Rounds One and Two, respectively. This is above the background level of 41,000 $\mu g/\ell$. Indicator parameters were generally within background ranges. However, background concentrations for ALK were exceeded at S1132 during Round Two (346,000 $\mu g/\ell$). At OPM-89-01, HARD, TDS, and specific conductance were all above background levels during both Rounds One and Two.

Interpretation. CL and SO4 were detected in groundwater at the Oleum Plant and Oleum Plant Pond above background concentrations. These concentrations appear to be isolated to the areas south of the Oleum Plant, and are most likely a result of spills and discharges from the Oleum Plant. The highest concentrations are detected in monitoring well OPM-89-01. This is a bedrock well with a much higher water level than the nearby overburden aquifer. The bedrock system has a lower hydraulic conductivity than the overburden aquifer. This condition likely results in a slow discharge of water from the bedrock into the overburden aquifer. This could lead to a reduction in the SO4 concentrations from the bedrock aquifer (170,000 to 200,000 $\mu g/\ell$ at OPM-89-01) to the overburden aquifer (76,000 to 74,000 $\mu g/\ell$ at OPM-89-03). The final observation from this groundwater data is that the Ballistics Pond does not appear to have a measurable influence on the groundwater quality.

Review of BAAP quarterly groundwater data through September 1992 from Oleum Plant and Pond, and Ballistics Pond monitoring wells indicates results are generally in agreement with the RI data. BAAP quarterly results indicate the presence of SO4 and CL in well OPM-89-01 at concentrations exceeding the WPALs, but rarely exceeding the WESs. These results are in agreement with the two rounds of RI data. No other contaminants of concern are identified in groundwater at these sites.

9.4.3 Summary of Contamination

High concentrations of AL and SO4 were detected in sediments collected from the Ballistics Pond and high concentrations of SO4 and NIT were detected in sediments collected at the Oleum Plant Pond. However, these high concentrations do not appear to impact the overall quality of the surface water at the Ballistics Pond. No surface water samples were collected at the Oleum Plant Pond as it holds little water.

High concentrations of SO4 were detected in the shallow soils collected from soil borings at the Oleum Plant and Oleum Plant Pond, but the concentrations decrease with depth. No identifiable source area for SO4 was detected in the borings.

Groundwater quality appears generally unimpacted in the vicinity of the Oleum Plant Pond and Ballistics Pond. However, SO4 and CL concentrations at or above the WPAL (125,000 $\mu g/\ell$) in monitoring well OPM-89-01 adjacent to and downgradient of the Oleum Plant indicate that groundwater quality has been impacted. The OPM-89-01 well is screened in bedrock that underlies approximately 70 feet of unsaturated overburden. It appears that groundwater, with high concentrations of SO4, discharges to the overburden aquifer resulting in diluted SO4 concentrations that are still above background. This is reflected in the SO4 concentrations detected at OPM-89-03 (74,000 to 76,000 $\mu g/\ell$) which are below those detected at OPM-89-01 but above those detected in background monitoring wells (maximum 41,000 $\mu g/\ell$). It should be noted that the SO4 concentrations do not exceed WPALs or WESs in the overburden aquifer in this area.

9.5 HUMAN HEALTH EVALUATION

9.5.1 Oleum Plant and Oleum Plant Pond

The Oleum Plant and Oleum Plant Pond are located near the northern boundary of BAAP surrounded by wildlife and open areas to the north and west and woodland to the south and east. The pond is a naturally low-lying area in which the water level varies considerably, often with no actual standing water. The area is described more fully in Subsection 9.1.

9.5.1.1 Chemicals of Potential Concern

Surface soil, subsurface soil, and sediment were sampled at the Oleum Plant and Pond. Surface water was not available as the pond is now usually dry. Compounds detected in these samples are listed in Appendix O, Tables O-71, O-72, and O-73 with frequency of detection, ranges of concentration, and rationale for exclusion given. The criteria for exclusion are described in Section 4.2. Compounds selected are summarized in Table 9-15.

9.5.1.2 Exposure Assessment

Grounds maintenance workers were evaluated for exposure to surface soil through incidental ingestion; construction workers were evaluated for exposure to soils to depths of 12 feet bgs through incidental ingestion and inhalation of particulates and volatiles; and future children playing at the pond area were evaluated for incidental ingestion of sediment. Although the pond area is low-lying and damp, there is usually no standing surface waters to be exposed to. A scenario evaluating incidental ingestion by a resident was also evaluated as a conservative comparison to the more likely ingestion scenarios. A farming scenario was not evaluated, because the Oleum Plant Area is surrounded by woods and bordered by a gully and is not currently being farmed. Intake was calculated using calculations and parameters described in Subsection 4.3.4.

9.5.1.3 Exposure Point Concentrations

Exposure point concentrations for the Oleum Plant are the maximum concentrations detected, as described in Subsection 4.3.5 and are listed in Table 9-15.

Exposure point concentrations for volatiles and chemicals on PM10 particles for the construction worker and the grounds maintenance worker scenarios are estimated by applying the calculation procedures described in Subsection 4.3.5. The results of the calculations are shown in Appendix O, Table O-77.

9.5.1.4 Risk Characterization

This subsection describes risk characterization at the Oleum Plant and Pond.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of daily intake of each chemical by each route were derived as described in Subsection 4.3.4. Chronic and subchronic RfD values for ingestion are shown in Table 4-6. RfCs for inhalation are listed in Table 4-9. Detailed calculations are in Appendix O, Tables O-74 through O-78. Absence of inhalation toxicity values precludes evaluation of that pathway for the grounds maintenance worker and a full evaluation for the construction worker. HQ values were summed across all chemicals and all pathways. The results are shown in Table 9-16. HI values are well below 1.0 even for the residential scenario, indicating that the chemicals and pathways evaluated at the Oleum Plant pose a minimal risk of noncarcinogenic effects.

Cancer Risks. No carcinogenic contaminants of potential concern by the oral route were found in Oleum Pond soils or sediments. Carcinogenic risks for inhalation were evaluated as described in Subsection 4.5. Estimates of intake were derived as described in Subsection 4.3.4. CSFs for inhalation are listed in Table 4-8. The calculations are shown in Appendix O, Table O-77. Conservatively using the inhalation slope factor for chromium VI for inhalation of particulates produced an excess cancer risk of 4×10^{-8} for a future construction worker. This risk falls below the USEPA target range.

Risks from PB. As described in Subsection 4.5, PB is evaluated by comparing detected concentrations to the interim cleanup level of 500 to 1000 ppm (USEPA, 1989c). The maximum concentration of PB in soils and sediment at the Oleum Plant and Pond was 18 μg/g (equivalent to ppm) which is below the cleanup level.

9.5.1.5 Summary of Risks at the Oleum Plant and Pond

Noncarcinogenic risks at the Oleum Plant and Pond are below the USEPA target level of 1. There were no carcinogenic contaminants of concern in surface soil or sediment. Excess carcinogenic risk from inhalation exposure to subsurface soil for a construction worker was below USEPA target range.

9.5.2 Ballistics Pond

The Ballistics Pond is located on the outwash plain in the northwestern corner of the BAAP site. The surrounding area is woodland. The pond itself is approximately 5 acres in size, reaches 20 feet in depth, and is a permanent, year-round water body. The water level of the pond is now much higher than in the past. This site is more fully described in Section 9.1.

9.5.2.1 Chemicals of Potential Concern. Compounds detected in sediment and surface water samples collected at the Ballistics Pond are listed in Appendix O, Tables O-79 and O-80. Information about frequency of detection, range of concentrations, and rationale for exclusion are based on the criteria described in Subsection 4.2. Analytes selected as compounds of potential concern are listed in Table 9-17.

9.5.2.2 Exposure Point Concentrations. Table 9-17 identifies the exposure point concentrations for COCs. The maximum detected concentration is used, as described in Subsection 4.3.5.

9.5.2.3 Exposure Assessment. The exposure scenario evaluated was for an older child playing and swimming at the Ballistics Pond in the future. Other scenarios were not considered, because only surface water and sediment from this permanent pond were sampled. Because the water level is now so much higher than in the past, areas that were surface soil during production years are now under water. Previous site assessment has not indicated that surface soil is contaminated.

9.5.2.4 Risk Characterization. *This subsection describes risk characterization* at the Ballistics Pond.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intake of each chemical by each route were derived as described in Subsection 4.3.4. RfD values are shown in Table 4-6. Detailed calculations are in Appendix O, Tables O-81 and O-82. HQ values were summed across all chemicals and all pathways. The results are shown in Table 9-18. The total HI value is well below 1.0, indicating that the chemicals and pathways evaluated at the Ballistics Pond pose minimal risk of noncarcinogenic effects.

Cancer Risks. No carcinogenic contaminants of concern were found in Ballistics Pond surface water. Carcinogenic risks from exposure to sediment were evaluated as described in Subsection 4.5. Daily intake by ingestion was estimated using equations and parameters described in Subsection 4.3.4. CSF values are given in Table 4-7. Calculation of carcinogenic risk is performed in Appendix O, Table O-81 and the results are shown on Table 9-18. The excess cancer risk for ingestion of sediment is estimated to be $5x10^{-9}$, which is well below the target risk range.

Risks from PB. The maximum concentration of PB in sediment, 54 ppm, does not exceed the interim cleanup range of 500 to 1000 ppm of PB.

9.5.3 Evaluation of Groundwater Contamination

Compounds detected in groundwater associated with the Oleum Plant and Pond and Ballistics Pond are listed in Table 9-19 along with the frequency of detection, range of detected concentrations, and federal and state standards. CR exceeds the PAL and NA exceeds the federal reporting level. No compounds exceed regulatory standards.

9.5.4 Discussion of Uncertainties

Uncertainties associated with the risk assessment process are discussed in Subsection 4.6.

9.5.5 Summary

Noncarcinogenic risks at the Oleum Plant and Pond are below the USEPA target level. There are no contaminants that are carcinogenic by the oral route. Incremental cancer risk by the inhalation route is below the USEPA target range. Concentrations of PB do not exceed the interim cleanup level.

Neither carcinogenic nor noncarcinogenic risks exceed USEPA target levels at the Ballistics Pond. Concentrations of PB are below the interim cleanup level.

No compounds in groundwater associated with the Oleum Plant and Pond and Ballistics Pond exceed standards.

9.6 BASELINE ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment for BAAP is to describe sensitive habitats and natural resource areas throughout the study area, focusing on the ecological communities at each BAAP site under investigation. In addition, baseline ecological effects associated with exposure to chemical constituents in ecological media at the facility are defined. The ecological assessment, conducted according to procedures outlined by USEPA, contains the following elements (USEPA, 1989a):

- Basewide Ecological Resource Areas (Subsection 2.2.6)
- Site Biological Characterizations (Subsection 9.6.1)
- Selection of Chemicals of Concern (Subsection 9.6.2)

- Ecological Risk Characterization (Subsection 9.6.3)

The general approach used to characterize ecological risk in this Baseline Ecological Assessment is summarized in Section 5.0.

9.6.1 Site Biological Characterizations

9.6.1.1 Oleum Plant and Oleum Plant Pond. The Oleum Plant, also situated near the northern boundary of BAAP, is in an area classified as a plant facility tract of land within the confines of the plant (Hellewell and Mattei, 1983). Biota expected to occur at or near this site are similar to those described for the Ballistics Pond area. However, the water level of the Oleum Pond varies considerably, and as a consequence, little emergent vegetation is associated with the aquatic habitat at this site. Because of the lack of emergent vegetation which would provide shelter and food resources for both aquatic and terrestrial fauna, and because much of the rest of the site has a gravel cover, the Oleum Pond is a considerably less favorable habitat than the Ballistics Pond.

9.6.1.2 Ballistics Pond. The Ballistics Pond is located in the northwest corner of BAAP and the overall surrounding area is classified as a woodland area tract (Hellewell and Mattei, 1983). The pond is approximately 5 acres in size and reaches a maximum depth of 21.5 feet (Tsai et al., 1988). To the north, the site is bounded by wooded areas containing species characteristic of upland hardwood forest (i.e., white oak (*Quercus alba*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and hickories (*Carya* spp.)). Scattered bigtooth aspen (*Populus grandidentata*) and cottonwood (*Populus deltoides*) are found in moister areas. Because of the proximity of the site to the forested habitat, various wildlife are expected to occur in vicinity of the site. These species include bird species such as the ruffed grouse (*Bonasa umbellus*), ring-necked pheasant (*Phasianus colchicus*), various seed-foraging small birds, and the red-tailed hawk (*Buteo jamaicensis*). Mammals likely to frequent the site include various rodents, Eastern cottontail (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), squirrels, and the red fox (*Vulpes vulpes*). Aquatic species expected to occur in the Ballistics Pond include white bass (*Roccus chrysops*), yellow perch (*Perca flavescens*), bluegill sunfish (*Lepomis macrochirus*), and fathead minnow (*Pimephales promelas*). A more complete species inventory is presented in Appendix P.

9.6.2 Selection of Chemicals of Concern

9.6.2.1 Oleum Plant and Oleum Plant Pond. Based on the aforementioned selection criteria, NIT and SO4 were chosen as compounds of concern for both the sediment and surface soil media (Table 9-20).

Significant surface water exposure to aquatic organisms is not anticipated at the Oleum Plant Pond and no surface water samples were collected. As a result, no compounds of concern were chosen for the surface water medium.

9.6.2.2 Ballistics Pond. Table 9-21 presents the compounds of concern selected for the Ballistics Pond surface water and sediment media; the compounds of concern include: AL, BA, CL, FE, MN, NIT, SO4, V, and ZN for surface water and AL, NH3, PB, NIT, SO4, B2EHP, and PHANTR for sediment.

No surface soil data are available and, consequently, no compounds of concerns were selected for this medium.

9.6.3 Ecological Risk Characterization

Risks to ecological receptors that may be exposed to site-related constituents at the Oleum Plant/Pond and the Ballistics Pond were characterized according to procedures presented in Subsection 5.5.

9.6.3.1 Oleum Plant and Oleum Plant Pond. Based on available data, there is little to suggest that Oleum Plant Pond sediment represents a substantial risk to aquatic organisms that could occur in this habitat. The HQ for NIT is well below 1.0 (Table 9-22). Although no toxicological data are available to evaluate the significance of the other compound of concern (i.e., SO4), it is unlikely that the exposure point concentration of 590 μg/g for this ubiquitous sediment constituent represents a serious threat to any aquatic lifeform.

Small mammals, such as the short-tailed shrew, are the only terrestrial receptors expected to be at risk for acute and chronic exposures. The HIs associated with both acute and chronic exposures exceeded 1.0; the HI associated with acute exposures only slightly exceeded 1, at 1.2 (Table 9-23). Under both acute and chronic exposure assumptions, sulfate is the only contributor of the estimated risk to this group of terrestrial receptors (Appendix R, Tables R-27 and R-28). The acute and chronic HIs estimated for this group of receptors suggest that impacts are possible. However, the site is not anticipated to be a preferred habitat for terrestrial receptors because of the gravel cover, lack of vegetation, and poorly developed soil.

HIs for the other modeled indicator species are lower than those estimated for small mammals. However, individual meadowlarks (and other birds with similar diets) and garter snakes (and other reptiles) that regularly forage in the vicinity of the Oleum Plant could also be impacted (chronic HIs are 0.7 and 0.52) for the bird and snake, respectively. Again, 100 percent of the overall chronic risk to these receptors is associated with dietary exposure to sulfates (Appendix R, Table R-58). Under acute exposure assumptions, no adverse effects to small birds and reptiles are expected.

9.6.3.2 Ballistics Pond. Only the exposure point concentration for ZN exceeded its criterion in Ballistics Pond surface water samples (Table 9-24). Given that the HQ for this constituent was only 1.4, it is unlikely that aquatic organisms would be impacted by the known contamination in this habitat. Similarly, only the sediment RTVs for NH3 and PB were exceeded by the estimated exposure point concentrations for Ballistics Pond sediment, and the magnitude of these exceedances are slight (see Table 9-24). These results do not suggest that substantial risk to aquatic (or semi-aquatic) organisms exist in this area.

9.6.4 Ecological Risk Assessment Conclusions

9.6.4.1 Effects to Aquatic Receptors. Sediment concentrations of NIT and SO4 at the Oleum Plant Pond are unlikely to pose a contamination threat to aquatic life forms, as indicated by the low HQ of NIT, and the low exposure point concentration and general ubiquity of SO4 in sediments. Although elevated, concentrations of ZN, NH3, and PB in the sediments and surface water at the Ballistics Pond are unlikely to pose any threat to aquatic receptors at this area based on low HQs for these constituents.

9.6.4.2 Effects to Terrestrial Receptors. Sensitive small mammals, such as the short-tailed shrew, are possibly at risk from surface soil exposures to SO4 at the Oleum Plant. However, the HQs and the conservative approach used to characterize risks would suggest that any impacts to ecological receptors would be minimal.

9.7 CONCLUSIONS OF THE BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

9.7.1 Oleum Plant and Oleum Plant Pond

Based on the human health and ecological evaluations, remedial action objectives are not warranted at the Oleum Plant and Pond.

9.7.2 Ballistics Pond

Both the human health and ecological evaluations indicate that remedial action objectives are not warranted at the Ballistics Pond.

9.7.3 Groundwater

The results of the baseline risk assessment indicates that remedial action objectives are unnecessary in this area.

10.0 OLD ACID AREA, OLD FUEL OIL TANK AREA

The Old Acid Area and Old Fuel Oil Tank Area are production and former storage facilities, respectively. As such they share similar geologic, hydrogeologic, and environmental settings, and are discussed together in this section.

10.1 CURRENT AND PAST DISPOSAL PRACTICES

The Old Acid Area and Old Fuel Oil Tank areas are located in the northwestern section of BAAP. Figure 10-1 shows the acid manufacturing facility and surrounding structures. Nitric acid and sulfuric acid manufacturing and handling activities occurred in this area. Two chemical releases have been recorded at the Old Acid Area since 1970 (Table 10-1). A release of 25 tons (exact constituents unknown) occurred between 1970 and 1972, because of storage tank leakage. On October 19 and 20, 1982, an estimated 6.5 tons of 92 percent sulfuric acid was spilled, also because of storage tank leakage. Following the spill the area was diked and the residual acid neutralized (Kearny, 1987). During the site reconnaissance, corroded concrete foundations and floors were observed throughout most of the Old Acid Area, indicating that small, numerous acid spills likely occurred during production periods.

Visual examination of the Old Acid Area was made from the five available aerial photographic sets. Surface processes were not identified that would indicate migration of chemicals from the immediate vicinity of the facility. The vegetative pattern around the site appears to remain essentially the same over time.

The Old Fuel Oil Tank Area is located south of the Old Acid Area and approximately 100 feet west of the Main Powerhouse. Figure 10-1 shows the approximate location of the former fuel oil storage tank, an aboveground tank in which No. 2 Fuel Oil was probably stored. The tank has been removed, and the size of the remaining concrete foundation structure suggests that tank capacity was approximately 6,000 gallons.

There is no documented evidence that details specific spills or releases of product from the Old Fuel Oil Tank. However, during excavation of a waterline in 1989, fuel oil was encountered in subsurface soil near the remaining concrete foundation. During mobilization for RI activities in 1989, ABB-ES personnel observed the excavation near the former tank and noted the presence of fuel oil odors and small seeps of oil or oily liquid from the wall of the excavation.

Olin reported an approximate 5,000-gallon spill in 1991 south and adjacent to the Old Fuel Oil Tank (see Table 10-1). The spill was the result of a subsurface pipeline rupture from a 10,000-gallon fuel oil tank not associated with the Old Fuel Oil Tank. This spill is currently being remediated by groundwater pumping. Further work on this spill is being conducted by Olin. Interpretation of the effects of spills from the Old Fuel Oil Tank on soils and groundwater are more difficult as a result of this 5,000-gallon spill.

10.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

Table 10-2 summarizes the field activities performed at the Old Acid Area and Old Fuel Oil Tank Area.

10.2.1 Soil Borings and Subsurface Soil Sampling

Three deep soil borings were drilled at the Old Acid Area and one deep soil boring was drilled at the Old Fuel Oil Tank Area between October 9 and 22, 1991. All borings were made by John Mathes and Associates, Inc., of St. Louis, Missouri, under subcontract to ABB-ES. In addition, ten shallow hand-auger borings were completed at the Old Acid Area by ABB-ES field personnel on October 3, 1991. The purpose of these borings and subsurface soil samples was to further characterize the nature and vertical distribution of chemicals at these sites. The logs of deep soil borings drilled during the RI are in Appendix D.

Two-foot long, 3-inch ID split-spoon samples were collected at 5-foot intervals in each 6.25-inch ID HSA soil boring from the ground surface to 30 feet bgs; and at 10-foot intervals from 30 feet bgs to the water table. Actual drilled footages, numbers of samples collected, and the purpose of the soil borings at the Old Acid Area and Old Fuel Oil Tank are listed in Table 10-3. Drilling and sampling equipment was decontaminated between samples and borings by steam-cleaning with water from Production Well No. 2.

At the Old Acid Area (Figure 10-2), the three deep borings (i.e., OAB-91-01 through OAB-91-03) were drilled downgradient or adjacent to the sulfuric and nitric acid concentration and storage facilities. Each HSA boring extended to the water table approximately 92 feet bgs. Split-spoon samples recovered for geologic logging (40 samples) and chemical analysis (15 samples) from these borings. Ten shallow borings (i.e., OAB-91-04 through OAB-91-13) were made in and around the Old Acid Plant production facilities to characterize the areal extent of shallow soil contamination. These borings were advanced to 2 to 3 feet bgs, and two soil samples (approximately zero to 1 foot bgs, and 2 to 3 feet bgs) were collected from each soil boring for laboratory analysis.

Two HSA borings, FTB-91-01 and FTB-91-02, were drilled at the location of the old fuel oil storage tank to characterize the type and vertical distribution of potential residual contamination (see Figure 10-2). These borings extended to depths of 89 to 92 feet bgs, and encountered the water table at approximately 90 feet bgs.

10.2.2 Monitoring Well Installations

Four new monitoring wells were installed at the Old Acid Area and Old Fuel Oil Tank Area. Three wells (OAM-89-01, OAM-89-02, and FTM-89-01) were installed by John Mathes and Associates, Inc., of St. Louis, Missouri, under subcontract to ABB-ES. OAM-91-01 was installed by Layne Environmental of Tempe, Arizona. These groundwater monitoring wells, in conjunction with existing wells installed during previous investigations, were sampled and tested to estimate hydraulic properties of the aquifer, the contour of the water table surface, and monitor the presence of chemicals in groundwater by sampling and analysis.

Monitoring wells OAM-89-01, OAM-89-02, and FTM-89-01 were installed using 6.25-inch ID HSAs; OAM-91-01 was installed using 6-inch ID and 10-inch OD dual-wall driven casing. All four wells were installed as water table monitoring wells that generally extended 7 to 15 feet into the water table.

Split-spoon samples were generally collected at 10-foot intervals from selected monitoring well borings advanced with HSAs to characterize subsurface geologic conditions. The monitoring wells, consisting of flush-threaded, 4-inch ID Schedule 80 PVC, were installed in boreholes at the completion of each boring. The PVC was supplied by Monoflex, Inc., of Largo, Florida, and Timco, Inc., of Sauk Prairie, Wisconsin. Well screen sections consisted of Schedule 80 machine-slotted PVC with 0.01-inch-wide openings. Well screen lengths were 10 and 20 feet for the water table wells. Well locations and installation depths are described in the following subsections.

The new wells at each site are identified with a letter prefix, OAM where OA indicates the site (i.e., Old Acid Area), and M indicates a single monitoring well. The number 89 indicates the year the well was installed. All wells installed at the Old Acid Area and Old Fuel Oil Tank Area were constructed as shallow water table monitoring wells. No nested clusters of wells were installed at these sites.

Water table wells have sandpacks placed in the annular spaces between the well screens and borehole walls or casings. The sandpacks for all wells generally extended 5 feet above the top of the screens. Water table wells had a 5-foot bentonite pellet seal above the sandpack. Type II cement/bentonite grout was placed above the pellet seal and extends to the ground surface. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated approximately 3 to 4 feet into the ground. A coarse 1- to 1.5-inch diameter stone blanket (6 inches thick) was placed around each protective casing.

Well installation diagrams with associated boring logs are in Appendix D, which also contains the well construction and backfill material types and approval sheets. Grout was allowed to set for a minimum of 48 hours before the wells were developed. Well development was completed with a compressed-air-operated positive displacement pump or a submersible pump. A minimum of five standing water well volumes were removed during the development process. Records of well development activities are contained in Appendix D.

Three monitoring wells, OAM-89-01, OAM-89-02, and OAM-91-01 were installed downgradient of the Old Acid Plant, in areas where former operations and tank leakage could have impacted groundwater quality. These wells are approximately 200 to 400 feet, south and southeast of the Old Acid Area. Locations of the new wells are shown in Figure 10-2. A summary of well information and siting rationale is in Table 10-4.

One shallow monitoring well, FTM-89-01, was installed approximately 150 feet south and downgradient of the Old Fuel Oil Tank spill area. The location of this new well is shown in Figure 10-2. A summary of well information and siting rationale is in Table 10-4.

10.2.3 Permeability Testing

To obtain an assessment of permeability variations within the unconsolidated aquifer at the site, a series of rising-head slug tests was performed on two new shallow monitoring wells at the Old Acid Area and Old Fuel Oil Tank Area. Water displacement for the rising-head tests was accomplished by physical displacement of water with a cylindrical slug. The water column was depressed by displacing water with a 2-inch diameter cylinder lowered 5 to 8 feet below the static water level. After allowing the water level to recover to its static condition, the slug was quickly withdrawn. As the water rose to its static level, data gathered for the rising-head test.

The rate of water level rise was recorded with a 20-psi pressure transducer and Hermit 2000 data logger, both supplied by In-Situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which can result in water level rebound above the static background level.

Generally, two to five tests were performed on each well to assess the variations associated with each test, evaluate any inertial effects associated with each well, and apply the maximum stress possible at each well. The test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected tests were also evaluated using Bouwer and Rice (1976) techniques (see Appendix I). Results of the Bouwer and Rice analyses compared favorably with Hvorslev results. Results of these analyses are summarized in Subsection 10.3.

10.2.4 Groundwater Sampling

Table 10-5 lists the five wells sampled during the RI at the Old Acid and Old Fuel Oil Tank Areas. Locations of all sampled wells are shown in Figure 10-2.

As part of the RI, ABB-ES conducted two rounds of sampling and analyses on these wells. Round One was conducted from November to December 1991 and Round Two was conducted during April and May 1992. The specific groundwater sampling procedures are described in the BAAP RI Sampling Design Plan developed by ABB-ES and reviewed by USATHAMA, WDNR, and USEPA (E.C. Jordan Co., 1989 and 1990c).

Before groundwater sampling, the water level and well depth in each well was measured to the nearest 0.01 foot and 0.1 foot, respectively. Water level data are presented in Appendix G and discussed in Subsection 10.3. Following these measurements, the new and existing wells were purged with a submersible pump. Purge volumes varied depending on standing water well volumes. Generally, purge volumes were five times the sandpack and well volume. Variances were documented and recorded on field data sheets and summarized in Appendix G. Purge water and groundwater samples were monitored in the field at the time of collection for temperature, pH, and specific conductance.

Groundwater samples were shipped to A.D. Little in Cambridge, Massachusetts (a USATHAMA-certified Laboratory) for the various analyses specific to each site. During the groundwater sampling effort, field sampling equipment was decontaminated by steam-cleaning with water from Production Well No. 2.

10.2.5 Summary of Chemical Analysis Schedule

Surface and subsurface soil samples as well as groundwater samples from the Old Acid Area and Old Fuel Oil Tank Area were selected for laboratory analysis. The following subsections summarize the chemical analysis schedule.

10.2.5.1 Laboratory Analytical Program. Table 10-6 summarizes the subsurface soil analytical matrix. Table 10-7 summarizes the groundwater analytical matrix.

ABB-ES' analytical subcontractors, A.D. Little, EA, and DataChem, used procedures consistent with the USATHAMA CLASS program, for analysis of groundwater, soil surface water and sediment samples. Analytical methods were certified under the CLASS program for all required analytes in water and soil. Analysis of several general water quality parameters (i.e., HARD, total ALK, and TDS) did not require certification. Chemical analytical methods are described in Subsection 4.2 of the Sampling Design Plans.

Reference information on the basis of USATHAMA methodology is contained in Appendix L. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings with certified reporting limits.

During the RI program, EA and DataChem analyzed all sediment, soil, and surface water samples, while A.D. Little analyzed all groundwater samples.

Table 10-6 also shows the analytical program completed for subsurface soil samples collected at the Old Acid Area and Old Fuel Oil Tank Area. The analyte matrix is based on the Tsai data and the substances reportedly used in these areas (Tsai et al., 1988). Analyses for subsurface soil samples from the Old Acid Area included metals (i.e., CD, CR, NI, and PB), the anions NIT and SO4, pH, and VOCs. Subsurface soil samples from the Old Fuel Oil Tank borings were analyzed for petroleum hydrocarbons, VOCs, and SVOCs.

10.2.5.2 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data from A. D. Little, EA, and DataChem, and the geotechnical data from the field drilling program.

Appropriate field data records were completed for each groundwater and surface soil sample (see Appendices D and G). Information on each well including the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, and sampling technique. A field notes section provides for any additional site information sampling personnel might need to include. Each well has a Monitoring Well Construction Diagram that documents structural details (Appendix D).

Where soil samples are taken from test borings, a Field Boring Log was completed. On this log, the driller and geologist record notes from the soil sampling event. The Field Boring Log and the field notes are both kept on file by ABB-ES. Samples were given unique site IDs for sample identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data was entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both the home office and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map File, Geophysical Groundwater Stabilized File, Geophysical Field Drilling File, Geotechnical Well Construction File, Chemical Groundwater File, and Chemical Soil File.

Chain-of-custody records along with ARFs were used to coordinate the transfer of samples from field sampling locations to the laboratory. Samples were divided into sample lots according to method, matrix, and analytical QC groups.

10.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The Old Acid and Old Fuel Oil Tank areas are located next to each other near the western BAAP boundary. Due to their close proximity, these sites share similar geologic and hydrogeologic conditions, and are described together in this subsection.

10.3.1 Surface Water Hydrology

Topographic relief in this area is on the order of 5 to 10 feet and is typical of glacial outwash plains where large quantities of sand and gravel were deposited in broad level plains beyond the terminus of the glacier.

The Old Acid and Old Fuel Oil Tank areas occupy approximately 25 to 50 acres. Numerous production-related buildings and roads exist in this area. Given the flat topography and highly developed nature of the area, all surface water drainage is controlled by excavated ditches and storm sewers.

10.3.2 Geology

Soil borings drilled at the Old Acid and Old Fuel Oil Tank areas encountered a stratigraphic sequence consistent with that observed at other areas on the outwash plain west of the Johnstown Moraine. This includes fill soils placed over a thick sequence of sand and gravel. Figure 10-3 shows the orientation of the geologic cross section presented in Figure 10-4. The geologic cross section depicts generalized stratigraphic conditions encountered in soil borings and monitoring wells.

The fine-grained loess layer typically encountered just below the ground surface at BAAP is generally missing or reworked in the Old Acid and Old Fuel Oil Tank areas. Immediately below the ground surface, fill soils consisting of tan-to-black, coarse-grained sands and gravels with significant silt content were encountered to depths of 5 to 15 feet. These soils were typically identified by a lack of stratification, a poorly sorted texture, and low and variable densities observed in Standard Penetration Tests. However, the contact or change from fill soils to natural soils was not always well-defined. In some areas, loess soils were encountered beneath the fill soils (i.e., OAB-91-01 and OAB-91-02).

Underlying the near surface fill and loess soils, a thick sequence of stratified sands and gravels typical of glacial outwash was encountered. Coarse-grained sands and gravels were encountered to a depth of approximately 20 to 25 feet immediately below the fill and loess. These coarse-grained soils were underlain by finer, more stratified sediments typically described as tan-to-brown, medium-fine sands stratified with occasional coarse sand and gravel layers and a few silty fine sand layers with some cross-bedding.

Borings and monitoring wells installed by ABB-ES at the Old Acid and Old Fuel Oil Tank areas did not encounter fine-grained silt and clay layers similar to those observed at depth in borings BGM-91-03 located approximately 3,500 feet south of the Old Acid Area. However, boring S1126, installed by Warzyn near the Old Acid Area approximately 500 feet east of FTM-89-01, did encounter silt and clay layers from 1 to 3.5 feet thick at the bottom of the boring (approximate elevation of silt and clay layers, 758 to 780 feet MSL). These fine-grained layers probably represent lacustrine soils initially deposited as lake sediments.

The borings installed in the Old Acid and Old Fuel Oil Tank areas were not extended to an elevation of 700 to 725 feet MSL, where the cobble-boulder zone was encountered at the Propellant Burning Ground and Settling Pond areas. It is likely this zone exists beneath the Old Acid and Old Fuel Tank areas given the location just west of the Johnstown Moraine.

Bedrock was not encountered in any of the borings installed in this area. However, bedrock was encountered at approximate elevation 795 feet MSL in background monitoring well BGM-91-01 approximately 2,500 feet north of the Old Acid Area. It is anticipated that bedrock, consisting of sandstones and shales from the Dresbach Group, underlies the Old Acid Area and Old Fuel Oil Tank Area at an approximate elevation of 690 to 670 feet MSL (see Figure 10-4).

10.3.3 Hydrogeology of Unconsolidated Sediments

This subsection discusses hydrogeologic conditions in the Old Acid and Old Fuel Oil Tank areas. This includes a detailed description of the major soil units, discussion of recharge rates, horizontal gradients, and hydraulic conductivity testing performed at this site.

As discussed in Subsection 10.3.2, the presence of a fine-grained silty loess immediately below the ground surface generally restricts the infiltration of precipitation, thereby limiting recharge to the underlying groundwater flow system to approximately 5 to 7 inches per year. However, where the loess unit has been stripped from the site for construction, the infiltration rates and corresponding recharge rates could be higher, on the order of 7 to 9 inches per year. Areas covered with asphalt or concrete pavement could have little or no recharge. These recharge estimates are based on water balance calculations and low-flow stream discharge measurements presented in Appendix H.

Underlying the fine-grained surficial soils is a thick sequence of sand and gravel. In this area, the upper 80 to 90 feet of the unit is unsaturated and constitutes a considerable vadose zone. Below the water table, an additional 90 to 100 feet of saturated sand and gravel constitutes the unconsolidated sand and gravel aquifer.

Hydraulic conductivity tests were performed at wells OAM-89-01 and FTM-89-01 by ABB-ES and at well S1126 by Warzyn. Test results are summarized in Table 10-8. Raw data, graphical plots, and calculations for tests conducted by ABB-ES are in Appendix I, and the raw data and calculations for tests conducted by Warzyn may be found in the EEI (1981). ABB-ES and Warzyn both used in situ slug withdrawal tests (see Subsection 10.3). Test results indicate a highly permeable aquifer with a range of 2×10^{-2} to 3×10^{-2} cm/sec for tests conducted by ABB-ES, and 7×10^{-3} cm/sec for the test conducted by Warzyn.

The lower hydraulic conductivity measured by Warzyn could reflect the presence of the silt and clay layers encountered at monitoring well S1126. Conversely, the lower hydraulic conductivity may reflect the well installation techniques. Warzyn used drilling muds during installation of the S1100-series wells, which can reduce hydraulic communication with the aquifer materials by clogging soil pores near the well screen.

10.3.4 Groundwater Movement

Figure 10-5 illustrates a water table contour plan for the Old Acid and Old Fuel Oil Tank areas. Groundwater flow is generally from the north-northwest to the south-southeast. Groundwater in this area flows toward the south-southeast, and turns toward the south further downgradient.

The water table contour plan illustrated in Figure 10-5 has horizontal gradients of approximately 0.001 ft/ft measured between wells OAM-89-01 and S1126 (see Appendix H for calculations). Vertical gradients were not calculated for this area, as there are no well nests available to measure the vertical water level variation. Based on observations from other areas of BAAP, vertical gradients are likely very small and insignificant in this area.

Groundwater flow velocity calculations were performed for the Old Acid and Old Fuel Tank areas using permeability estimates based on slug test data. The analyses indicate a velocity range of 85 to 125 ft/yr.

10.4 NATURE AND EXTENT OF CONTAMINATION

10.4.1 Introduction

The contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in soil and groundwater at the Old Acid and Old Fuel Oil Tank areas at BAAP. Chemicals that represent site-related contamination were identified based on the evaluations of soil and groundwater sample analytical results as compared to background concentrations; frequency of occurrence and concentrations of each chemical; and the relationship of chemicals to past activities. Because of their proximities, it is both convenient and expedient to group the Old Acid Area and Old Fuel Oil Tank Area together in the following discussion.

Data collected before January 1988 were summarized in the MEP (Tsai et al., 1988). These data contained inconsistencies because of the use of differing analytical methods, sampling techniques, and protocols. However, these data are used to augment the description of contaminant nature, distribution, and behavior.

Chemical data tables downloaded from the IRDMIS are contained in Appendix K. Within each section, results of chemical analyses are presented by medium. Chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). Indicator parameters are nonspecific measurements that grossly characterize water quality. The indicator parameters measured in the laboratory program were HARD, ALK, and TDS. Field indicator parameters, temperature, pH, and specific conductance were also measured during the field program. These parameters are used, where appropriate, to assist in site-specific data interpretation. Chemical-specific numerical standards and criteria used to evaluate chemical data are listed in Table 3-3, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WESs, and WPALs.

Appendix L details specific results of the data quality assessment. This includes (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, (2) a listing of USATHAMA-certified analytical methods used by the subcontractor laboratories, (3) a summary of the laboratory quality control sample results and impact on associated field sample results, (4) a summary of nontarget, library searched VOC and SVOC compounds detected in the RI analytical program, and (5) a summary of USATHAMA-approved laboratory control charts.

The primary chemical observed at the Old Acid Area was SO4, which was found in soil samples collected within the Old Acid Plant. SO4 was not detected in groundwater samples collected in the vicinity of this SWMU.

Soil samples at the site of the Old Fuel Tank indicate the presence of fuel-related compounds in the soil. The SVOCs, 2MNAP and 2,3,6-trimethylnaphthalene (236TMN), were detected in the shallow samples, suggesting that residual fuel could be present on the soil surface. NNDPA was also detected in subsurface soils from the Old Fuel Oil Tank Area.

10.4.2 Contamination Assessment

Table 10-9 summarizes detected analytes for surface and subsurface soil. Table 10-10 summarizes detected analytes for Rounds One and Two of the groundwater sampling.

10.4.2.1 Surface and Subsurface Soils. During the RI, subsurface soil samples were collected from the Old Acid Area to assess potential impacts of acid production and spills. All borings were located within and adjacent to the acid-generating facilities. Three of the borings (OAB-91-01 through OAB-91-03) were deep soil borings advanced to the water table. The remaining borings (OAB-91-04 through OAB-91-13) were shallow, advanced 2-to 3-feet bgs. Analysis of the samples from these borings focused on anions (SO4 and NO3) with pH, selected metals (CD, CR, PB, and NI), and VOCs analyzed in the samples from deep borings. Within the Old Acid Area, 35 samples were collected for laboratory analysis with 23 of these samples collected from depths less than 2 feet bgs.

At the Old Fuel Oil Tank Area, subsurface soil samples were collected to assess the impact of fuel oil spills. The borings (FTB-91-01 and FTB-91-02) were located next to the former fuel oil tank foundation and were advanced to the water table. Analysis of the samples from these borings focused on petroleum hydrocarbons, VOCs, and SVOCs. Ten samples were collected for laboratory analysis with two of the samples from depths less than 2 feet bgs.

VOCs. At the Old Acid Area, the only VOCs detected were ACET, CH2CL2, and MEK. These detects were at trace levels near the certified reporting limit. CH2CL2 was detected in the method blank samples associated with groundwater samples from this site. ACET and MEK have been detected in other method blank samples at BAAP (see Appendix L). As such, these results are not considered to reflect soil contamination. No other VOC compounds were detected in the shallow and deep soil samples collected from borings OAB-91-01, 02, and 03.

At the Old Fuel Oil Tank Area, VOCs were not detected in the 10 subsurface soil samples submitted for analyses from borings FTB-91-01 and 02.

SVOCs and Petroleum Hydrocarbons. At the Old Acid Area, no SVOCs were detected in the soil samples collected from the deep soil borings. At the Old Fuel Oil Tank Area, 10 compounds were detected at relatively low concentrations. Five compounds (2MNAP, ANAPNE, BGHIPY, FANT, and FLRENE) were detected only in the 7-foot sample from FTB-91-01 where high photoionization detector (PID) readings, visual observations, and odors suggested the presence of residual fuel oil. Three of the remaining compounds were detected in the 7-foot and 12-foot samples from FTB-91-01 (BAANTR, CHRY, and PHANTR). These compounds are either related to fuel oil or fuel oil by-products.

In boring FTB-91-02, a trace concentration of the fuel-oil-related compound BAANTR was detected at concentrations of 0.122 and 1.380 μg/g in the 2-foot and 89-foot bgs soil samples, respectively. The only other compound detected at FTB-91-02 was B2EHP, at trace levels (1.23 to 1.80 μg/g in samples from 6 and 11 feet bgs).

TPHC was detected in soil samples from FTB-91-01 at concentrations of 430 and 1,180 μg/g in samples from 2 and 7 feet bgs, respectively, where field observations indicated odors, visible staining, and PID readings similar to fuel oil. TPHC was not detected in the 12-foot bgs sample but at 17 feet bgs it was again detected at a concentration of 21.8 μg/g. TPHC was not detected in any other samples from FTB-91-01 or FTB-91-02. It appears residual fuel oil compounds are largely being retained in the upper 7 to 10 feet of the soil column, where the silt content in the soil is higher.

Inorganics (Metals and Anions). At the Old Acid Area, selected metals (CD, CR, NI and PB) were analyzed in the samples from the deep borings while anions (NIT and SO4) were analyzed in the samples from all borings. No metals or anion analyses were conducted on samples from the borings at the Old Fuel Oil Tank Area.

Of the 23 soil samples collected from depths less than 2 feet bgs at the Old Acid Area, the sample from OAB-91-01 at 2 feet bgs had metals concentrations above background, with PB at 1,500 μg/g and NI at 56.9 μg/g above background. Of the

12 deeper subsurface soil samples, several had metal concentrations above background concentrations. Elevated metals concentrations were detected in OAB-91-02 at 7 feet bgs (PB at 240 $\mu g/g$) and OAB-91-01 at 6 feet bgs (PB at 64 $\mu g/g$). These results do not suggest significant contamination by metals in the surface or subsurface soils at the Old Acid Area.

Samples from the Old Acid Area were also analyzed for the anions NIT and SO4. NIT was detected in most soil samples although the concentrations were not considered significant. In the 23 surface soil samples, nine indicated no detectable NIT concentrations and the remaining 14 had concentrations between 1.09 and 1.79 $\mu g/g$. NIT concentrations in the 12 deeper subsurface soil samples, ranged from 1.24 to 8.28 $\mu g/g$.

SO4 analyses indicate elevated concentrations above background. Of the 23 surface soil samples, eight had SO4 concentrations between 130 and 20,000 $\mu g/g$. However, these concentrations decreased with depth in the three deep soil borings as illustrated in Figure 10-6. SO4 was detected at 2,500 $\mu g/g$ in boring OAB-91-02 at 7 feet bgs. All other sample results are below 350 $\mu g/g$. The maximum concentration of SO4 detected at the water table is 27.4 $\mu g/g$ in boring OAB-91-02. The elevated SO4 concentrations likely reflect spillage and leakage of sulfuric acid during production activities.

Interpretation. Subsurface soil samples collected from the Old Acid Area indicate high concentrations of SO4. The high concentrations of SO4 are limited to the upper section of the unsaturated zone, and appear not to have migrated to groundwater. This distribution is expected based on the chemistry of SO4, and the insoluble salts it can form in soils.

Results from samples collected in soil borings FTB-91-01 and 02 indicate that soil in the immediate vicinity of the Old Fuel Oil Tank has been impacted by fuels. Fuel-related SVOCs are present in the upper 12 feet of soil at FTB-91-01, and appear not to have migrated to groundwater.

10.4.2.2 Groundwater. Table 10-10 summarizes the detected compounds found during the Round One and Round Two groundwater sampling efforts. This table lists analytes with detectable concentrations in one or more of the samples from the Old Acid and Old Fuel Oil Tank areas. Overall, the results indicate high SO4 concentrations downgradient of the Old Acid Area at the Old Fuel Oil Tank Area. No Old Fuel Oil Tank related compounds were detected. For a compound to be considered representative of actual site conditions, it must be detected in at least two rounds of sampling at a given well.

VOCs. Three VOCs were detected in the groundwater sampling: ACET, CH2CL2, and CHCL3. ACET and CH2CL2 detects are associated with laboratory method blank contamination (see Appendix L). As such, these compounds are not considered site-related compounds. CHCL3 was detected in three wells (OAM-89-02, FTM-89-01, and S1126) at trace levels (maximum concentration 3.22 $\mu g/\ell$). All CHCL3 detects are illustrated in Figure 10-7, and are below the WES but above the WPAL. At well OAM-89-01, CHCL3 was only detected during Round Two and, therefore, is not considered a confirmed compound. At wells FTM-89-01 and S1126, CHCL3 was detected during both sample rounds. However, the concentrations are at trace levels, and the results are not adequate to suggest a well-defined contaminant plume. The Old Fuel Oil Tank is not a likely source for CHCL3 as fuel oil does not typically contain chlorinated compounds. It should be noted that the CHCL3 detects occur in wells downgradient from the Old Acid Area, and could reflect low level groundwater impacts from this site. At FTM-89-01, the CHCL3 detects could be related to the high concentration of CL detected in the well (see discussion). No source for the CHCL3 detected was noted in soils during the RI.

SVOCs and Petroleum Hydrocarbons. The Old Fuel Oil Tank well (FTM-89-01) was sampled for SVOCs and petroleum hydrocarbons. No SVOCs or petroleum hydrocarbons were detected during Round One or Round Two sampling at this well. It appears the residual contamination associated with the Old Fuel Oil Tank is not reaching the water table. This agrees with the distribution of petroleum hydrocarbons noted in the subsurface soil samples from soil boring FTB-91-01.

Inorganics (Metals and Anions). The Old Acid Area wells (OAM-89-01, OAM-89-02, OAM-91-01, and S1126) were sampled for CA, CD, CR, NA, NI, and PB. Of these analytes, only CA, CR, and NA were detected in the analytical results. Although the CR concentrations did exceed the WPAL during Round One, the concentrations fell to below the certified reporting limit in Round Two. A similar condition with CR concentrations has been observed in nearly all the wells at BAAP.

The anions NIT, CL, and SO4 were analyzed in all wells from the Old Acid and Old Fuel Oil Tank Areas. NIT concentrations were often above the WPAL of 2,000 $\mu g/\ell$ during Round One (ranging from 1,500 to 5,400 $\mu g/\ell$), but typically dropped below the WPAL during Round Two (ranging from 1,100 to 2,200 $\mu g/\ell$). These concentrations are typical of the elevated NIT detected across BAAP as well as in background wells within or adjacent to areas influenced by agricultural practices. CL and SO4 concentrations had similar distributions. Concentrations are within or near background levels at all wells except FTM-89-01, where the concentrations are well above background (880,000 to 1,200,000 μg/ℓ for CL and 360,000 to 410,000 μg/ℓ for SO4). No clear sources for these contaminants have been identified.

The indicator parameters measured at each well indicate high levels of specific conductance and total dissolved solids at well FTM-89-01 where CL and SO4 concentrations are elevated.

Summary and Interpretation. Review of groundwater monitoring data and comparison with both background levels and WES shows no significant groundwater contamination at the Old Acid Area. There is no substantial VOC contamination in groundwater. SO4 at high concentrations in the soil has not significantly affected the groundwater.

FTM-89-01 was installed approximately 30 feet downgradient of the former fuel oil tank. CHCL3, detected below the WES at concentrations of 1.11 to 1.9 μg/ℓ, was the only VOC reported in samples from FTM-89-01. The low level of CHCL3 could be related to the high concentration of CL detected in this well. High concentrations of CL could be related to deicing salts used on the adjacent parking lot to the west. Elevated concentrations of SO4 detected in groundwater from FTM-89-01 might be related to spills and or leakage from the Old Acid Area. No SVOCs or petroleum hydrocarbons were detected in samples from FTM-89-01.

Review of BAAP quarterly groundwater data through September 1992 from Old Acid Area and Old Fuel Oil Tank Area monitoring wells indicates results are generally in agreement with the RI data. BAAP quarterly results indicate the presence of PB in well OAM-91-01 at concentrations exceeding the WPAL, but not exceeding the WES, in June and September 1992. CHCL3, which was detected in several wells sampled during the RI, was not detected in BAAP quarterly analyses probably due to higher detection limits of the quarterly analyses. NIT was detected in all wells at concentrations consistently exceeding the WPAL, but less than the WES. No other contaminants of concern are identified in groundwater at these sites.

10.5 HUMAN HEALTH EVALUATION

10.5.1 Old Acid Area

The Old Acid Area described in detail in Subsection 10.1, is located in the northwestern section of the BAAP directly adjacent to the Old Fuel Tank Area. Various buildings associated with storage and production activities are located in the area. The ground surface is covered with a layer of crushed gravel. The Old Acid Area is surrounded by plant tract.

10.5.1.1 Chemicals of Potential Concern. Soil borings were drilled in the Old Acid Area. Samples from the zero to 2 feet bgs level were used to represent surface soil. Samples to 12 feet bgs were used for subsurface soil. Compounds detected in surface and subsurface soils at the Old Acid Area are listed in Appendix O, Tables O-83 and O-84, along with frequency of detection, range of detected concentrations, and rationale for exclusion as described in Subsection 4.2. Chemicals selected as compounds of potential concern are listed in Table 10-11.

10.5.1.2 Exposure Assessment. Exposure to surface soil was evaluated for a grounds maintenance worker by oral and inhalation routes. In addition, exposure for a future resident by the oral route was evaluated to use as a conservative comparison. Exposure to surface through subsurface soil was evaluated for a construction scenario via the oral and inhalation routes. The area is isolated from other cropland and is too small for crops, so a farming scenario was not evaluated.

10.5.1.3 Exposure Point Concentrations. Exposure point concentrations for surface soil at the Old Acid Area are the maximum concentration detected in the zero to 2 feet bgs samples from soil borings. The exposure point concentrations for the construction worker scenario are based on the compounds of concern and their respective maximum values for soils from zero to 12 feet bgs.

Exposure point concentrations for volatiles and chemicals on PM10 particles are estimated by applying the calculation procedures described in Subsection 4.3.5.

10.5.1.4 Risk Characterization. This subsection describes the risk characterization for the Old Acid Area.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3.4. Chronic and subchronic RfD values are shown in Table 4-6. RfCs were not available for COCs here, so the inhalation route could not be evaluated. Detailed calculations are in Appendix O, Tables O-85 through O-88. HQ values were summed across all chemicals and the results are shown in Table 10-12. HI values are well below the USEPA target of 1.0, indicating that chemicals and pathways evaluated at the Old Acid Area pose minimal risk of noncarcinogenic effects. The addition of the inhalation pathway would not be likely to raise the HI above 1.0.

Cancer Risks. The only carcinogenic contaminant of concern by the oral route was PB and it is evaluated separately below. Carcinogenic risks from inhalation of particulates were evaluated as described in Subsection 4.5. Intake was estimated using equations and parameters described in Subsection 4.3.4. CSF values for inhalation are given in Table 4-8. Calculation of risk is performed in Appendix O, Table O-88 and the results are shown in Table 10-12. The excess cancer risk of $2x10^{-8}$ falls below the target range.

Risks from PB. The risks from PB are evaluated by comparing soil concentrations to the interim cleanup level of 500 to 1,000 ppm (USEPA, 1989c). The maximum concentration of PB detected at the Old Acid Area is 1,500 ppm, indicating that exposures to PB may pose a potential risk to human health. The interim cleanup level is developed to be protective of residential exposures for children. Only one soil sample was available for the Old Acid Area, so there is considerable uncertainty about average lead concentrations at the site. Risks from exposure to lead are expected to be minimal based on the conservative cleanup level and the fact that residential exposure is not expected to occur.

10.5.1.5 Summary of Risks at the Old Acid Area. Concentrations of PB in the soil exceed the USEPA interim cleanup level.

10.5.2 Old Fuel Oil Tank

The Old Fuel Oil Tank Area, located south of the Old Acid Area and west of the old powerhouse, is described in Subsection 10.1. The aboveground tank used to store No. 2 fuel oil has been removed but the concrete foundation on which it stood remains. The remaining area is paved or covered with crushed gravel. Various storage and production buildings are adjacent to the Old Fuel Oil Tank Area.

10.5.2.1 Chemicals of Potential Concern. The criteria outlined in Subsection 4.2 were used to choose chemicals of potential concern for the Old Fuel Tank Area. All compounds detected are listed in Appendix O, Table O-89, including frequency of detection, range of detected concentrations, and rationale for exclusion. Chemicals selected as compounds of potential concern are listed on Table 10-13.

10.5.2.2 Human Exposure Levels. Only subsurface soil was analyzed, because the surface is covered with paving, concrete, buildings or crushed gravel. The scenario evaluated was for the ingestion and inhalation routes during construction activity.

10.5.2.3 Exposure Point Concentrations. Maximum detected concentrations in soils from zero to 12 feet bgs are used as the exposure point concentrations and are listed in Table 10-13.

10.5.2.4 Risk Characterization. This subsection describes the risk characterization for the Old Fuel Tank Area.

Noncarcinogenic Risks. Noncarcinogenic risks were evaluated as described in Subsection 4.5. Estimates of average daily intakes of each chemical by each route were derived as described in Subsection 4.3.4. Subchronic RfD for ingestion values are shown in Table 4-6. RfCs are not available for compounds of concern. Detailed calculations are in Appendix O, Tables O-90 and O-91. HQ values were summed across all chemicals and all pathways. The results are shown in Table 10-14. Because no RfCs were available, noncarcinogenic risks from inhalation could not be quantified. The HI value for ingestion is well below the USEPA target of 1.0, indicating that the chemicals evaluated at the Old Fuel Tank Area pose a minimal risk of noncarcinogenic effects by that route.

Cancer Risks. Excess lifetime cancer risks for both oral and inhalation routes were estimated as described in Subsection 4.5. Estimates of lifetime average daily intakes were derived as described in Subsection 4.3.4. CSFs used in these calculations are shown in Tables 4-7 and 4-8. Detailed evaluations of risk estimates are in Appendix O, Tables O-90 and O-91. Carcinogenic risk levels for ingestion and inhalation are shown in Table 10-14. The total carcinogenic risk of 9×10^{-9} is below USEPA's target range.

Risk from PB. PB was not detected in the soil at the Old Fuel Oil Tank.

10.5.2.5 Summary of Risks at the Old Fuel Oil Tank. Based on the human health risk calculations, there are no contaminants of potential concern at the Old Fuel Oil Tank area.

10.5.3 Evaluation of Groundwater

The nature and extent of contamination of groundwater at this area are discussed in Subsection 10.4.3. The compounds of concern are listed in Table 10-15, which includes information on frequency of detection, range of detected concentrations, and federal and state standards. CHCL3, CR, and NIT were detected at concentrations exceeding WPALs, but not exceeding WESs. Although concentrations of CL and SO4 exceed secondary drinking water standards and NA exceeds a federal reporting level, these compounds generally do not exceed federal or state regulatory standards.

10.5.4 Discussion of Uncertainties

Uncertainties involved in the risk assessment process are described in Subsection 4.6.

10.5.5 Summary

Carcinogenic and noncarcinogenic risks at the Old Acid Area are below target levels. Concentrations of PB in the soil exceed the interim cleanup level but pose a limited risk to likely potential human receptors.

Noncarcinogenic and carcinogenic risks from soils at the Old Fuel Tank are within acceptable limits.

Concentrations of compounds in groundwater at the Old Acid and Old Fuel Oil Tank areas are within acceptable limits.

10.6 BASELINE ECOLOGICAL ASSESSMENT

The purpose of the ecological assessment for BAAP is to describe sensitive habitats and natural resource areas throughout the study area, focusing on the ecological communities at each BAAP site under investigation. In addition, baseline ecological effects associated with exposure to chemical constituents in environmental media at the facility are defined. The ecological assessment, conducted according to procedures outlined by USEPA, contains the following elements (USEPA, 1989a):

- Basewide Ecological Resource Areas (Subsection 2.2.6)
- Site Biological Characterizations (Subsection 10.6.1)
- Selection of Chemicals of Concern (Subsection 10.6.2)
- Ecological Risk Characterization (Subsection 10.6.3)

The general approach used to characterize ecological risk in this Baseline Ecological Assessment is summarized in Section 5.0.

10.6.1 Site Biological Characterizations

The Old Acid Area and Old Fuel Tank Area are two sites directly adjacent to each other in the northwest part of BAAP; both are within a plant facility tract. Various buildings associated with storage and production activities are located in this area and crushed gravel covers much of the remaining land surface. Consequently, little vegetation other than weedy herbaceous plants such as various mustards (*Lepidium* spp.), cocklebur (*Xanthium* sp.), and Queen Anne's lace (*Daucus carota*) occur here. Because of the nature of the habitat and the isolation from wooded areas, the only fauna expected in the general vicinity of these two sites are seed-foraging birds and small rodents such as the house mouse (*Mus musculus*) and deer mouse (*Peromyscus maniculatus*).

10.6.2 Selection of Chemicals of Concern

10.6.2.1 Old Acid Area. Summarized data for the Old Acid Area are presented in Table 10-16; NI, NO3, PB, and SO4 were chosen as surface soil compounds of concern for this area.

10.6.2.2 Old Fuel Oil Tank Area. No compounds of concern were chosen for the Old Fuel Tank Area because no surface soil data are available.

10.6.3 Ecological Risk Characterization

Risks to ecological receptors that may be exposed to site-related constituents at the Old Acid Area and the Old Fuel Oil Tank Area were characterized according to the procedures presented in Subsection 5.5.

10.6.3.1 Old Acid Area. Ecological receptors that occur at the site are expected to be at risk for acute and chronic exposures. The HIs associated with both acute and chronic exposures exceeded 1.0 and ranged over several orders of magnitude (Table 10-17). These results suggest that small mammals, such as the short-tailed shrew, are at greatest risk from exposure to surface soil constituents at the Old Acid Area (HIs for acute and chronic exposures are 2,800 and 57,000, respectively). Under both acute and chronic exposure assumptions, PB accounted for most of the estimated risk to this group of terrestrial receptors (Appendix R, Tables R-29 and R-30). In addition, nickel was determined to be a risk contributor to small mammals for acute exposures. The acute and chronic HIs estimated for this group of receptors are sufficiently high to suggest that impacts are likely.

HIs for the other modeled indicator species are lower than those estimated for small mammals. However, individual meadowlarks (and other birds with similar diets) and garter snakes (and other reptiles) that regularly forage in the vicinity of the Old Acid Area would also likely be impacted (chronic HIs are 180 and 2,000 for the bird and snake, respectively). Approximately 100 percent of the overall chronic risk to these receptors is associated with dietary exposure to PB (Appendix R, Table R-60). Under acute exposure assumptions, impacts to small birds and reptiles are also likely; PB is the sole risk contributor under acute exposure assumptions for these two types of terrestrial receptors.

Estimated HIs for the large predatory receptors (i.e., red fox and red-tailed hawk) ranged from 1 to 10 (Table 10-17) indicating that adverse effects are possible for members of these feeding guilds as well. However, large predatory species probably do not forage regularly at the Old Acid Area because of lack of suitable habitat in the vicinity and frequent human activity in the area. Consequently, these conclusions are somewhat theoretical in that they are based on possible, rather than anticipated, exposures by these predatory species. PB is the most significant contributor to the overall estimated risk; nickel and sulfate contribute (approximately 1 percent) to the total HIs.

10.6.4 Ecological Risk Assessment Conclusions

Small mammals such as the short-tailed shrew and the house mouse are likely to be at risk from exposure to PB in surface soil at the Old Acid Area, as indicated by the sufficiently high acute and chronic HIs for PB estimated for this group of receptors. Individual meadowlarks and garter snakes would also likely be impacted by dietary exposure to PB. Although PB surface soil concentrations within the range of naturally occurring background concentrations were estimated to adversely impact ecological receptors (particularly small mammals) at the Old Acid Area, actual exposures may be considerably less than was assumed in the risk model due to the limited suitability of the habitat (i.e., limited forage base, lack of nesting areas and frequent human activity). These factors would limit the presence of wildlife at the study area as well as the amount of PB they were exposed to while there transiently.

An ecological risk characterization was not conducted for the Old Fuel Oil Tank Area; however, significant exposures are considered unlikely because of the poor habitat quality and the frequent human activity in the area.

10.7 CONCLUSIONS OF THE BASELINE HUMAN HEALTH AND ECOLOGICAL ASSESSMENTS

10.7.1 Old Acid Area

The human health and ecological assessments indicate that remedial action objectives are not warranted at the Old Acid Area.

10.7.2 Old Fuel Oil Tank

The human health evaluation does not indicate that remedial action objectives are necessary at this site. No ecological evaluation was performed because access to surface soil is limited by concrete and gravel ground covers.

10.7.3 Groundwater

The groundwater evaluation for this area indicates remedial action objectives are not warranted.

11.0 OFF-POST AREA SOUTH OF BAAP

11.1 INTRODUCTION

Based on data from groundwater sampling along the southern BAAP facility boundary, it has been established that the contaminant plume originating at the Propellant Burning Ground has migrated off-post to the south. To assess potential off-post impacts, BAAP conducted a residential and irrigation well sampling program in 1990. After this, ABB-ES conducted a high capacity, irrigation well survey to generate a regional water table contour map and better assess the direction of groundwater flow in the sand and gravel aquifer south of BAAP (Appendix H). The regional water table contour plan was then compared with the regional groundwater flow model (see Section 2.0).

The results of these efforts were integrated to more optimally site a series of monitoring wells south of BAAP as illustrated in Figure 11-1. These wells were installed in two separate phases, five wells in 1990 and 19 wells in 1991. The wells installed during 1990 were sampled twice (September and October, 1990 Round I and II, respectively) before installation of the second phase of wells in 1991. After the 1991 installations, all the off-post wells were included in the facility-wide RI Round One (November/December 1991) and Round Two (April/May 1992) sampling program. The results of this program are discussed in this section.

11.2 FIELD PROGRAM DESCRIPTION AND RATIONALE

The following subsections describe the field program activities and rationale. Table 11-1 summarizes the field program elements. Conduct of the field program was specified in the following documents: (1) Sampling Design Plan (Data Item A004), (2) QC Plan (Data Item A006), and (3) HASP (Data Item A009).

11.2.1 Monitoring Well Installations

During the off-post work, 24 monitoring wells were installed at nine locations from August 2 to 24, 1990, and September 26 to November 11, 1991 by Layne Environmental of Tempe, Arizona under subcontract to ABB-ES. These groundwater monitoring wells were utilized to provide data to estimate hydraulic properties of the aquifer, rate and direction of groundwater flow, contours of the water table, and to monitor the presence of chemicals in groundwater.

Borings for the monitoring wells were advanced using 10-inch OD dual-walled driven casing employing reverse air circulation for cuttings return. Disturbed soil samples were collected at 10-foot intervals from each boring to generally log the type and nature of soils encountered. At locations where more than one boring/well was being installed, only the deepest soil boring was logged.

Intermediate and deep monitoring wells, screened from 20 to 150 feet below the water table were installed in the borings. Shallow wells (i.e straddling the water table) were not installed, as it was determined that the contaminant plume at the base boundary occurred at depth below the water table. The monitoring wells were constructed with flush-threaded, 4-inch ID Schedule 80 PVC supplied by Monoflex Inc. of Largo, Florida. Screen intervals consisted of 10-foot sections of Schedule 80 PVC with 0.010-inch machine-slotted openings. Table 11-2 summarizes specifications of the off-post monitoring well installations.

Sandpack material placed around each well screen generally extends 5 feet above the top of the well screen although, in some of the deeper overburden wells, the sandpack extended somewhat higher as a result of soil heave during well placement. Above the sandpack, a 20-foot thick bentonite slurry seal was placed. Finally, the remainder of the annular space was filled with a Type II cement/bentonite grout. Protective steel casings with locking covers and keyed-alike locks were placed over the well riser pipes and seated approximately 3 to 4 feet into the ground. A coarse 1- to 1.5-inch stone blanket (6 inches thick) was placed around each protective casing.

The new off-post wells are identified with a letter prefix, PBM or SWN, where PB and SW indicate the site (i.e., Propellant Burning Ground and Southern Well, respectively), M indicates a single monitoring well, and N indicates a group of nested wells. Off-post wells have the two identifiers because of their time of installation. The 1990 "PB" wells were established to locate the VOC plume whose apparent source is the Propellant Burning Ground. The 1991 "PB" and "SW" wells were installed to more accurately define the plume boundaries. The number 90 or 91 indicates the year the well was installed. Well screen designations A, B, C, D, and E represent progressively deeper installation intervals. The E suffix represents a bedrock well.

Well installation diagrams with associated boring logs are in Appendix D. Grout was allowed to set for a minimum of 48 hours before the wells were developed. Well development, accomplished using a submersible pump, consisted of pumping the well while raising and lowering the pump through the screened section of the well. During development, each well was pumped a total of five standing water well volumes plus three times the estimated volume of water lost during well installation were purged from the well. Appendix D contains records of well development activities.

11.2.2 Permeability Testing

To obtain an assessment of permeability variations within the overburden and bedrock aquifer, a series of rising-head slug tests was performed on four of the deep monitoring wells located off-post south of BAAP. Data from these tests supplement the 56 slug tests performed on monitoring wells at BAAP, as well as the aquifer test performed at extraction well BCW-3 in the southern Propellant Burning Ground. Water displacement for the rising-head tests was accomplished by pressurizing the well casing. At the deep monitoring wells, the water column was typically depressed from 2 to 9 feet by sealing the well casing at the wellhead and pressurizing the well with compressed breathing air. Precautions were taken to ensure that air was not forced into the aquifer. This was accomplished by placing an electronic water level probe above the well screen to alert the operator when the water level was approaching the screened interval. The water level was allowed to return to a static condition after releasing the air pressure. As the water rose to its static level, data was gathered for the rising-head test.

The rate of water level rise was recorded with a 20-psi pressure transducer and Hermit 2000 data logger, both supplied by In-Situ, Inc. Care was taken to apply the maximum allowable stress to the aquifer without generating excessive inertial effects, which occasionally resulted in water level rebound above the static background level.

Generally, two to three tests were performed on each well to assess the variations associated with each test, evaluate the inertial effects associated with each well, and to determine the maximum stress possible to apply at each well. The test data were evaluated using the Hvorslev Analysis (Hvorslev, 1951). Selected tests were also analyzed by the Bouwer and Rice (1976) technique (see Appendix I). Results of the Bouwer and Rice analyses compared favorably with Hvorslev results. Results of these analyses are summarized and discussed in Subsection 11.3.2.

11.2.3 Groundwater Sampling

Table 11-3 lists the 24 monitoring wells sampled during the RI. As required in the WDNR In-Field Conditions Report, the sampling program included three residential water supply wells south of, and one east of, BAAP (WDNR, 1987). Locations of the residential wells (i.e., Graf, Premo, Schaefer, and Spear) are shown in Figure 11-2. Two separate groundwater sampling episodes were undertaken off-post by ABB-ES. In September and October of 1990, two limited rounds of groundwater samples (1990 Round I and 1990 Round II) were collected from the 1990 series wells (PBM-90-01D, PBM-90-02D, PBM-90-03D, and PBN-90-04B,D) off-post. Samples were collected from the monitoring wells and analyzed by DataChem Laboratories for the following VOCs: 11DCE, 11DCLE (Round II only), 12DCE, 12DCLE (Round II only), CCL4, CHCL3, and TRCLE. Only select VOCs were analyzed in an attempt to more clearly define the off-post VOC plume. Two complete rounds of groundwater samples were collected in November and December of 1991 (Round One) and April and May of 1992 (Round Two) from all monitoring wells located off-post. The specific groundwater sampling procedures are described in the BAAP RI Sampling Design Plan developed by ABB-ES, and reviewed by USATHAMA, WDNR, and USEPA (E.C. Jordan Co., 1989 and 1990c).

Before groundwater sampling, the water level and well depth in each well were measured to the nearest 0.01 and 0.1 foot, respectively, using an electronic water level meter. Water level data tabulated in Appendix F are discussed in Section 11.3.2. Following these measurements, the wells were purged with a submersible pump. Purge volumes varied depending on standing water well volumes. Generally, five times the sandpack and well volume were purged before sampling. Variances were documented and recorded on field data sheets and summarized in the tables in Appendix G. Purge water and groundwater samples were monitored in the field at the time of collection for temperature, pH, and specific conductance. Groundwater field sampling data records are summarized in Appendix G.

During the sampling program, the field sampling equipment was decontaminated by steam-cleaning with water from Production Well No. 2.

Following sample collection, preservation, and packing, all groundwater samples were shipped to A.D. Little, Inc., in Cambridge, Massachusetts (a USATHAMA-certified Laboratory) for the various analyses specific to each sample.

11.2.4 Summary of Chemical Analysis Schedule

Groundwater samples from the off-post monitoring wells and residential wells were selected for laboratory analysis. The following subsections summarize the chemical analysis schedule.

11.2.4.1 Laboratory Analytical Program. Table G-1 in Appendix G lists the analyses completed on groundwater samples from each well sampled during the RI. Table 11-4 summarizes the groundwater analytical matrix.

The following discrepancy between the ABB-ES Sampling Design Plan (1991) and final analytical results should be noted:

- The Graf residential well was not sampled during Round One as the resident could not be contacted.

ABB-ES' analytical subcontractor, A.D. Little, used procedures consistent with the USATHAMA CLASS program for analysis of groundwater. Analytical methods were certified under the CLASS program for all the required analytes in water. Chemical analytical methods are listed in Appendix G and described in Subsection 4.2 of the Sampling Design Plans.

Reference information on the basis of USATHAMA methodology is contained in Appendix G. Included are matrix-specific method numbers, respective instrumentation or procedures used, and analyte listings with certified reporting limits.

11.2.4.2 Data Management. Data generated through implementation of the BAAP RI was managed in accordance with USATHAMA data management procedures. Data for this project included the chemical analysis data from A.D. Little and the geotechnical data from the field drilling program.

For each well sampled, a Groundwater Field Data Record sheet was completed. This sheet contains specific information on each well. Information such as the project name, sample site ID, sampling date, field sample number, weather, well depth, water level, sampling equipment, and sampling technique is recorded. A field notes section provides for any additional site information sampling personnel might need to include. These field data records are included in Appendix G. Each well has a Monitoring Well Installation Data Record that documents structural details (see Appendix D).

A Field Boring Log was completed for each monitoring well location. On this log, the driller and geologist record notes from the soil sampling event. The Field Boring Logs are included in Appendix D. Samples were given unique site IDs for sample identification. These site IDs are the primary means for accessing data in the IRDMIS. Geotechnical field data has been entered by ABB-ES directly into the IRDMIS. Field-generated data was entered on ABB-ES field log forms and field daily report forms for transmission to both the home office and USATHAMA. Data entered into the IRDMIS by ABB-ES and/or the subcontractor laboratory included the following files: Geophysical Map File, Geophysical Groundwater Stabilized File, Geophysical Field Drilling File, Geotechnical Well Construction File, and Chemical Groundwater File.

Chain-of-custody records along with ARFs were used to coordinate transfer of samples from field sampling locations to the laboratory. Samples were divided into sample lots according to method, matrix, and analytical QC groups.

11.3 GEOLOGY AND GROUNDWATER CHARACTERIZATION

The off-post area south of BAAP is located in the outwash plain west of the Johnstown Moraine. Glacial outwash and glacio-fluvial deposits were expected in this area.

11.3.1 Geology

Soil borings and monitoring wells installed south of BAAP encountered a near-surface, fine grained loess deposit underlain by approximately 200 to 220 feet of coarse-textured sands and gravel over bedrock. Bedrock in this area is composed of interbedded sandstones and carbonate units. As this area is located west of the Johnstown Terminal Moraine, the soils appear to be largely outwash materials. No glacial tills were encountered in any soil borings in this area. The orientation of geologic cross sections depicting generalized stratigraphic relationships among the major soil units is presented in Figure 11-3. The cross sections themselves are presented in Figures 11-4, 11-5, and 11-6. The cross sections present only generalized relationships interpreted from conditions encountered in specific borings. Significant changes could occur between soil borings.

At the ground surface, a dark brown to black fine-grained silty soil unit was encountered in nearly all soil borings. This unit is a loess deposit consisting of windblown fine sand, silt, and clay. Boring logs indicate the unit is up to 8 feet thick, although the dual-walled drilling technique used at the site often resulted in limited cuttings return near the ground surface from which to make geologic observations.

Coarse-textured soils were encountered beneath the loess and were typically described as poorly sorted sands with gravels. At some locations, substantial gravel deposits were encountered underlying the loess. At approximate elevation 720 to 740 feet MSL (about 90 to 110 feet bgs), a coarser grained sand and gravel deposit was encountered. The elevation of this unit corresponds well with the coarse-grained gravel unit encountered at depth below the Propellant Burning Ground (see Figure 11-6). B-series monitoring wells were typically screened in this unit.

Below the coarse-grained sand and gravel layer, variably textured sands with gravel approximately 50-to-70 feet thick were again encountered. C-series wells were generally installed in this layer. These sands extended to just above the bedrock surface, where another coarse-grained sand and gravel layer was encountered. D-series wells were generally installed in this lower sand and gravel unit.

Bedrock was encountered at boring SWN-91-03E at 210 feet bgs (approximate elevation 625 feet MSL), and a bedrock monitoring well was installed. A total of 48 feet of bedrock was penetrated for this installation. The top 10 feet of bedrock is described as a blue-gray fine-grained dolomite. This was followed by 15 feet of tan to brown medium-grained sandstone. The final 23 feet of the boring penetrated additional blue-gray dolomite. Monitoring well SWN-91-03E was screened in the sandstone unit.

South of SWN-91-03E, bedrock dips to an elevation of approximately 610 feet MSL at PBM-90-02D and 590 feet MSL at PBN-90-04D (Figure 11-6).

11.3.2 Hydrogeology of Unconsolidated Sediments

This Subsection describes the hydrogeologic setting of the off-post area south of BAAP. The hydrogeology of this area, as with much of BAAP, is dominated by the highly permeable sand and gravel aquifer in the coarse-grained outwash soils discussed in Subsection 11.3.1.

The silty loess unit at the ground surface likely acts to limit the infiltration of precipitation. Recharge rate estimates based on water budget analysis and low-flow stream discharge records suggest a recharge rate on the order of 5 to 7 inches per year (see Appendix G for presentation of this analysis). Below the silty loess, a substantial vadose zone, on the order of 75 feet thick, overlies the water table. Groundwater recharging the aquifer must pass through this unit before reaching the water table.

Horizontal groundwater flow in this area is largely influenced by the WP&L dam on the Wisconsin River. The water level in the Lake Wisconsin Reservoir north of the dam (approximate elevation 774 feet MSL) is substantially higher than the water table elevation in the adjacent sand and gravel aquifer (approximate elevation 760 to 745 feet MSL). This head difference prohibits discharge of groundwater into the reservoir in this area. Rather, groundwater flows south, parallel to the reservoir in this area, before turning east and discharging to the Wisconsin River south of the WP&L dam. As illustrated in Figure 11-7, groundwater flow in the off-post area south of BAAP is within the region where groundwater flow is curving from a southerly flow direction to an easterly flow direction.

In this area, where groundwater flow is turning to discharge to the Wisconsin River, flow-lines are generally converging, and to accommodate this, the horizontal gradients are somewhat steeper than in the on-post area. Horizontal gradients measured in this area range from 0.0019 to 0.0030 ft/ft. Steeper gradients were measured between the wells located closer to the WP&L dam while the flatter gradients were measured between wells located further from the WP&L dam.

Vertical gradients measured at the various well nests indicate no substantial upward or downward flow components. This was expected, given the coarse, relatively homogeneous nature of the aquifer materials. The maximum vertical gradient measured is only 0.004 ft/ft (measured at well clusters PBM/N-90/91-01C and D and PBM/N-90/91-02C and D). Minor vertical gradients such as these could reflect slightly different flow velocities between different layers or variations in the precision of the water level measurement.

Upward vertical flow gradients are expected near the WP&L dam and between the bedrock and overburden groundwater flow systems. Upward vertical gradients are expected adjacent to, and downgradient of, the WP&L dam where groundwater is flowing upward to discharge into the Wisconsin River. Given the gradients measured at the SWN-91-05 and PBN-90/91-01 well clusters, it appears the upward gradients associated with the WP&L dam do not extend to this area. General upward vertical gradients were expected from the underlying bedrock into the overburden flow system as the deep regional bedrock flow system also discharges to the Wisconsin River. However, upward gradients were not detected at SWN-91-03D and E where wells are screened in the overburden and bedrock, respectively. Apparently, at this location, the water levels in the bedrock flow system more closely reflect the water levels in the overburden flow system than the deeper bedrock flow system. It is likely that upward gradients would exist at deeper depths in the bedrock flow system.

Hydraulic conductivity tests were performed at monitoring wells SWN-91-03B, C, D, and E by ABB-ES. Test results are summarized in Table 11-5, while the raw data and graphical analytical plots are presented in Appendix I. The test results indicate a highly permeable aquifer with hydraulic conductivity values ranging from $1x10^{-2}$ to $2x10^{-2}$ cm/sec. These results are consistent with the slug test results obtained from on-post monitoring wells at BAAP. The extraction well (BCW-3) aquifer test performed in the southern Propellant Burning Ground indicated a somewhat higher hydraulic conductivity of $6.9x10^{-2}$ cm/sec. The slug test conducted at SWN-91-03E indicates a hydraulic conductivity of $1.0x10^{-3}$ cm/sec in the underlying bedrock aquifer. The results suggest the sandstone bedrock aquifer has a slightly lower hydraulic conductivity than the overburden aquifer.

Groundwater flow velocities for the overburden aquifer were calculated using the horizontal gradient data and the hydraulic conductivity test results presented above. The calculations indicate a groundwater flow velocity range of 80 to 680 feet/year. This range is comparable to, although somewhat higher than, the on-post flow velocities calculated at BAAP. The higher velocities reflect the steepened gradients and the converging flow lines associated with groundwater flow around the WP&L dam.

11.4 NATURE AND EXTENT OF CONTAMINATION

11.4.1 Introduction

This contamination assessment describes the nature, distribution, and migration potential of chemical contamination detected in groundwater at off-post wells south of BAAP. Chemicals that represent site-related contamination (CCL4, TRCLE, and CHCL3) were identified based on the groundwater sample analytical results from on-post monitoring wells and off-post irrigation and residential wells. Because of the probable extension of a VOC plume off-installation to the south of the Propellant Burning Ground, Olin Corporation has sampled private potable supply wells and irrigation wells south and southeast of the BAAP boundary. Groundwater samples were collected from these off-post wells and analyzed for the VOCs TRCLE, CCL4, CHCL3, and 12DCE. These analyses were not performed in accordance with the approved QA/QC Plan for this project, but are suitable for screening purposes. The off-post well data, discussed in this Subsection, form the basis for the initial siting of the five 1990-series off-post monitoring wells. Subsequent sampling of the 1990-series wells enabled siting of the 24 1991-series off-post monitoring wells.

Chemical data tables downloaded from the IRDMIS are contained in Appendix K. Within this section, results of chemical analyses for off-post monitoring well samples (Table 11-6) and residential well samples (Table 11-7) are presented and discussed. Chemicals are discussed in the order of organic chemicals (i.e., VOCs and SVOCs), followed by inorganic chemicals (i.e., metals, anions, and indicator parameters). Indicator parameters are nonspecific measurements that grossly characterize water quality. The indicator parameters measured in this program were HARD, ALK, and TDS. These parameters are used, where appropriate, to assist in site-specific data interpretation. Chemical-specific numerical standards and criteria used to evaluate the data are listed in Table 3-3, including federal MCLs and MCLGs, federal AWQC for human health and aquatic life, WESs, and WPALs. Chemical data tables downloaded from the IRDMIS are contained in Appendix J. Appendix L details specific results of the data quality assessment. This includes (1) a review of Production Well No. 2 (decontamination source water) laboratory analysis, (2) a listing of the USATHAMA-certified analytical methods used by the subcontractor laboratories, (3) a summary of the laboratory quality control sample results and impact on associated field sample results (4) a summary of nontarget, library searched VOC and SVOC compounds detected in the RI analytical program and impact on associated field sample results, and (5) a summary of the USATHAMA-approved laboratory control charts.

11.4.2 Contamination Assessment

11.4.2.1 Groundwater Data from Private Wells.

BAAP Data. Information collected during the RI suggested that VOCs associated with the Propellant Burning Ground plume have migrated south of the BAAP facility boundary. To address this possibility, irrigation and residential wells located south of BAAP were sampled and analyzed for site-related VOCs.

Samples were collected from April to June 1990 by Olin Corporation and analyzed for the primary VOCs identified at the Propellant Burning Ground. The analyses were conducted by an independent laboratory that was not USATHAMA-certified. As a result, most of the data are not yet available through the IRDMIS. Results of available data are summarized in the following paragraphs.

CCL4 was detected in samples from four of the 13 irrigation and residential wells sampled south of the installation. Each well is located within the predicted pathway of the deep CCL4 plume emanating from the installation. Highest concentrations were reported in an irrigation well (130 μg/ℓ) and a domestic well (80 μg/ℓ) south of BAAP. Both wells draw water from the sand and gravel aquifer. The results support the interpretation that CCL4 is present in the deeper portion of the sand and gravel aquifer south of the Propellant Burning Ground. Contamination has not been detected in wells that draw water from the bedrock aquifer.

TRCLE was also identified as a component of the VOC plume at the Propellant Burning Ground. TRCLE was detected once in one of the private wells at a concentration less than 0.5 μg/ℓ. As discussed in Subsection 6.2.4.1, the absence of significant concentrations and sporadic detections of TRCLE suggest this compound has not migrated as far as CCL4.

CHCL3 was detected in 11 of the 13 wells. In most of the wells, CHCL3 was detected at concentrations less than the 5 μg/ℓ WES. The WES was exceeded in three domestic supply wells and one irrigation well. The highest reported concentration of CHCL3 was 50 μg/ℓ. In subsequent samples collected at this well, CHCL3 concentrations decreased to below certified reporting limits. In this well, it is possible the CHCL3 could have resulted from cleaning or disinfecting the well system before sampling. No method blank or trip blank results were supplied with the BAAP data. CHCL3 is a common laboratory contaminant, and if present in the trip blanks and method blanks, the CHCL3 could be attributed to the laboratory.

In addition to samples collected at the off-post private wells by BAAP, ABB-ES collected samples from four private water supply wells in the RI sampling program as per requirements of the WDNR In-Field Conditions Report. The four private wells were assigned the site identifications Graf, Premo, Schaefer, and Spear. The locations of these wells are shown in Figure 11-2, and Table 11-7 summarizes the analytical results. Premo, Schaefer, and Graf are located south of the installation boundary, and Spear is located beyond the northeastern boundary.

The objective of sampling these wells was to assess the impacts, if any, of off-installation migration of chemicals identified within the installation. The target compounds analyses of these samples included VOCs, SVOCs, metals, NIT, and SO4.

Site-related VOCs were generally not detected in the four residential wells sampled. Although CH2CL2 was detected in all samples, its presence in this sample is also associated with laboratory method blank contamination. The only other VOC found was a 0.584 $\mu g/\ell$ detect of CHCL3 in the Premo well during Round Two. This concentration is below the laboratory certified reporting limit of 0.83 $\mu g/\ell$ and the WPAL of 0.6 $\mu g/\ell$ for CHCL3. Previous sample analyses from this well have not detected CHCL3.

Although the Premo, Schaefer, and Graf wells are located south of the VOC plume emanating from the Propellant Burning Ground, they have not been affected. The wells are located east (in the case of Premo) and west (in the case of Schaefer and Graf) of the estimated path of the plume. No SVOCs were detected in any of these wells during either sampling Round One or Round Two.

As with all monitoring well sampling results, the metals analyses at the four residential wells indicated the presence of CR during Round One with concentrations ranging from 19.6 to 28.6 $\mu g/\ell$. However, during Round Two, CR was not detected in any of the sample results. A similar condition has also been noted with respect to FE concentrations. Detection of CR in Round One groundwater samples is discussed in Subsection 11.4.2.2.3.

The only other metal detect of interest is HG, which was detected at 3.25 $\mu g/\ell$ in the Schaefer well. This result is above the WPAL and WES for HG. However, it should be noted that HG is not a site-related contaminant detected in groundwater, and was not detected during Round One. Additional sample results are needed to assess if the HG detect reflects actual water quality in the aquifer.

NIT was detected in most samples with concentrations ranging from below the certified reporting limit of 5.26 $\mu g/\ell$ in the Round Two sample from the Schaefer well, to 9,300 $\mu g/\ell$ in the Round One sample from the Spear well. The Premo and Spear wells had maximum NIT concentrations of 8,000 and 9,300 $\mu g/\ell$, respectively. These concentrations are above the WPAL of 2,000 $\mu g/\ell$, but are below the WES of 10,000 $\mu g/\ell$. These NIT concentrations are less than the maximum background concentration of 10,000 $\mu g/\ell$, and are likely related to agricultural practices in the area.

CL and SO4 were detected in the residential well samples. The detected concentrations were generally within background ranges with minor exceptions, specifically for SO4. At the Graf well, SO4 was detected at 60,000 μg/ℓ during Round Two (maximum background concentration measured was 41,000 μg/ℓ). At the Spear well, SO4 was detected at a concentration of 44,000 and 42,000 μg/ℓ which is only slightly above the maximum background concentration. None of these results approached the WPAL of 125,000 μg/ℓ for SO4.

11.4.2.2 Groundwater Data from Monitoring Wells. A summary of the groundwater chemical data is presented in Table 11-6. It should be noted that Table 11-6 lists only analytes with detectable concentrations in one or more of the samples from the off-post monitoring wells.

11.4.2.2.1 Volatile Organic Compounds.

As discussed above, VOCs were detected in the groundwater in several private irrigation and domestic wells south of BAAP. The monitoring wells installed by ABB-ES are oriented in two separate transects, a northern transect installed with SWN-series wells and a southern transect with PBM/N-series wells. Each location has a cluster of two to four wells. The transects and clusters are situated to better assess the geometry and extent of the plume in the off-post area. Results from the four separate sampling rounds have shown good agreement between the sample rounds. Generally, the results have indicated very low to trace concentrations of VOCs well below the maximum concentrations detected in the private wells (see Tables 11-6 and 11-7).

The principal site-related VOCs detected south of BAAP are CCL4, TRCLE, and CHCL3. Figure 11-8 illustrates the distribution of the detected compounds in Rounds One and Two in the monitoring wells south of BAAP. VOCs other than CCL4, TRCLE, and CHCL3 detected in these wells are attributed to laboratory method blank contamination (see Appendix L). CHCL3 was detected in two wells, SWN-91-02C and SWN-91-03B, along the northern transect at concentrations ranging from below certified reporting limits to 1.31 μg/ℓ. At the southern well transect, CHCL3 was detected in two wells, PBM-90-02D and PBN-91-02B, at concentrations ranging from below certified reporting limits to 0.594 μg/ℓ.

Within the northern transect, CCL4 was detected in three wells in the central cluster (SWN-91-03B, C and D) of the northern transect. Concentrations in these wells ranged from below certified reporting limits to 10.8 $\mu g/\ell$ between Rounds One and Two. Within the southern well transect, CCL4 was detected in two wells, PBN-91-02B and PBM-90-02D, at concentrations ranging from below certified reporting limits to 3.53 $\mu g/\ell$ (PBM-90-02D). As discussed in Subsection 11.2.3, the 1990-series wells were sampled shortly after their installation (Rounds I and II). Results from the 1990 effort indicate that CCL4 was detected in well PBM-90-02D at 1.68 $\mu g/\ell$ (Round II sampling effort). No other site-related VOCs were detected in either the Round I or Round II sampling efforts.

TRCLE was detected less frequently than CCL4. TRCLE was only detected in the northern well transect in monitoring wells SWN-91-03B and D at concentrations ranging from below certified reporting limits to 0.425 $\mu g/\ell$. TRCLE was not detected in any wells in the southern transect.

VOC concentrations detected in the various monitoring wells are generally below those detected in the private wells within the plume area. These variations could be a result of the monitoring wells coming to equilibrium with the surrounding aquifer. In many samples, the Round Two detects indicate higher contaminant concentrations of VOCs. The higher VOC concentrations in private wells could also be a result of screen placement within more highly concentrated zones of the contaminant plume.

The outer well clusters established along both the northern transect (SWN-91-01B, C and D and SWN-91-05B, C and D) and the southern transect (PBM/N-90/91-01C and D and PBN-90-04B and D) delineate the maximum lateral boundaries of the plume. Based on the results obtained from SWN-91-03 and the PBM/N-90/91-02 well clusters, the boundaries of the plume can be more narrowly defined, as illustrated in Figure 11-9.

11.4.2.2.2 Semivolatile Organic Compounds.

No site-related SVOCs were detected in the off-post monitoring wells south of BAAP. The only SVOC detected regularly was B2EHP. However, the B2EHP is a component of PVC well materials and often results in B2EHP detects in new monitoring well installations. This condition was observed in the new 1991-series off-post monitoring wells. PBN-91-03B was the only 1991-series well where B2EHP was not detected. At five of the 1991-series wells where detectable concentrations of B2EHP were measured in Round One, no

B2EHP was detected in Round Two. PBN-90-04D was the only 1990-series well where B2EHP was detected (90.8 and 71.8 μg/ℓ in Rounds One and Two, respectively). These results combined with the on-post groundwater data, which do not indicate a B2EHP contaminant plume, suggest that B2EHP detections are related to the PVC well screen and casing materials, and are not indicative of aquifer contamination.

11.4.2.2.3 Inorganics (Metals and Anions).

The metals detected above WPALs in groundwater samples from off-post monitoring wells south of BAAP include CR, CD, and PB. No samples had metals concentrations exceeding the WES. The spatial and temporal distribution of these metals results does not suggest a site-related contaminant plume. The distribution of these metals is illustrated in Figure 11-10. All metals analyses for the off-post monitoring wells were conducted on field-filtered, acid-preserved samples, and reflect dissolved metals concentrations.

As with the on-post metals analyses during Round One, CR was detected in nearly all off-post monitoring wells with concentrations ranging up to 14.5 μg/ℓ, and all but two samples had concentrations less than 8.5 μg/ℓ. In Round Two, CR was not detected in any of the off-post monitoring wells. Potential sources of laboratory contamination and procedures were reviewed to explain these metal data. No definitive sources of laboratory contamination or problems with methods were found. In addition, field records were checked and field personnel questioned; standard field sampling practices were followed during both rounds of groundwater sampling. Although definitive conclusions about the source of CR bias have not been reached, the following observations can be made: (1) CR was present in method blank samples during Round One but not Round Two, (2) standard-matrix spike recoveries for CR were higher during Round One (Appendix L), (3) CR was detected in laboratory analyses from monitoring well and production/residential well samples in Round One but not in Round Two, and (4) the same lot of acid preservative used in Round One was also used in Round Two. Given these observations, it appears the CR detected in Round One groundwater samples is the result of a laboratory bias.

CD and PB were the only other metals that exceeded the WPAL. Detection of CD and PB were sporadic, indicating these metals occur naturally in the groundwater and are not likely occurring as a contaminant plume. CD was detected in only one monitoring well, PBM-90-01D, during Round One, with a concentration of 2.78 $\mu g/\ell$. This is slightly above the WPAL of 1 $\mu g/\ell$. CD was not detected in any wells during Round Two.

PB was not detected in any off-post monitoring well during Round One. PB was detected in only one monitoring well, SWN-91-02D during Round Two, with a concentration of 5.6 $\mu g/\ell$. This result is slightly above the WPAL of 5 $\mu g/\ell$ for PB.

NIT was the only anion detected at concentrations above the WPAL and WES in the off-post monitoring wells south of BAAP. The NIT concentrations appear to reflect region-wide cultural influences (e.g., agriculture, septic systems). No BAAP site-related NIT plume can be associated with these results. Overall, the on-post NIT concentrations in groundwater are less than those measured off-post.

Eight wells had NIT concentrations above the WES of 10,000 $\mu g/\ell$ in at least one round of groundwater sampling (see Table 11-6). The maximum concentration, 27,000 $\mu g/\ell$, was detected in monitoring well PBN-91-02B during Round One. The remaining 16 monitoring wells had NIT concentrations in excess of the WES, but above the WPAL (2,000 $\mu g/\ell$) during both sample rounds. The only exception to this occurred at SWN-91-03D, where the Round Two sample had a NIT concentration of 1,300 $\mu g/\ell$, which is below the WPAL. Generally, higher NIT concentrations were detected in the shallower water table wells.

11.4.3 Summary of Contamination

The groundwater sampling program at private water supply wells and off-post monitoring wells south of BAAP identified a contaminant plume of CCL4, CHCL3, and TRCLE migrating south from the southern BAAP boundary. Maximum concentrations of these compounds were detected in private irrigation wells. However, the array of off-post wells installed along the two transects south of BAAP identified the maximum lateral extent of the plume. Vertically, the plume appears to be contained within the overburden aquifer. Samples collected from bedrock monitoring well SWN-91-03E near the center line of the plume has not detected any site-related VOCs.

Review of BAAP quarterly groundwater data through September 1992 from off-post private wells and monitoring wells are generally in agreement with the RI data. CCL4 and CHCL3 are the principle contaminants, detected in monitoring wells, exceeding the WPAL and occasionally exceeding the WES. VOCs were not detected in the four private wells of Premo, Schaefer, Spear, and Graf. The notable difference between the BAAP quarterly data and the RI data is the detection of CCL4 at concentrations less than 5 $\mu g/\ell$ in BAAP samples taken in October 1992 from wells SWN-91-02C,D, SWN-91-03E, SWN-91-04C, and PBN-91-02C. Further monitoring of these wells will verify the validity of these results. CCL4 was not detected in these wells during the two RI sampling rounds.

11.4.4 Environmental Fate of Contaminants

The chemical and physical behavior of major contaminants found in off-post groundwater are described in terms of how they affect the environmental fate, and especially migration potential, of the contaminants. Table 11-8 lists the VOCs considered major contaminants detected in off-post groundwater, and summarizes their chemical and physical properties. Table 11-9 tabulates results of a simple contaminant migration model for CCL4 and TRCLE based on partitioning retardation factors, groundwater velocity, and travel times.

The extent of CCL4 in off-post groundwater points to a significant on-post source (or past source) in the Propellant Burning Ground Area. CCL4 is expected to move with groundwater, but to be somewhat retarded by organic carbon in the aquifer matrix. The predicted environmental half-life of CCL4 in aqueous solution undergoing hydrogenolysis is 7,000 years. Hydrogenolysis is defined as a reduction in which a carbon-halogen bond is broken and hydrogen replaces the halogen substituent (Vogel, et al., 1987). Eventually, CCL4 will either be degraded, or diluted by dispersion in groundwater to below certified reporting limits.

TRCLE was detected at trace levels in groundwater from off-post private wells and monitoring wells. TRCLE is expected to move with groundwater, also being somewhat retarded by organic carbon in the aquifer matrix. Reductive dechlorination of TRCLE via microbiological activity under anaerobic conditions to form DCEs can occur (Vogel, et al., 1987). The predicted environmental half-life of TRCLE in aqueous solution undergoing hydrogenolysis is 0.9 years (Vogel, et al., 1987). The presence of TRCLE degradation products was not detected in groundwater samples from off-post wells. Ultimately, TRCLE will be either degraded, or diluted through dispersion in groundwater or by other degradative mechanisms to below certified reporting limits as it is transported south of BAAP.

CHCL3 was also detected at trace levels in groundwater from off-post wells. Based on the low K_{oc} of this compound, CHCL3 is expected to move more quickly than CCL4 and TRCLE in an aquifer containing organic carbon. Current data suggest that sorption is not an important process in the aquatic fate of CHCL3. The predicted environmental half-life of CHCL3 in aqueous solution ranges from 1.3 to 3,500 years (Vogel, et al., 1987). Ultimately, CHCL3 will either be degraded, or diluted below certified reporting limits by mixing with groundwater as it is transported south of BAAP.

11.4.5 Model of Groundwater Contaminant Transport. CCL4 has been detected off-post as far south as well PBN-90-02D. A simple model is used to estimate the distance CCL4 has traveled over time. This transport model, described in the Superfund Exposure Assessment Manual, is based on the assumption that contaminants in groundwater will be retarded according to their adsorption affinities for soil as represented by distribution coefficients (USEPA, 1988c). The equation used is as follows:

$$V_c = V/[1+K_d(b/n)]$$

where

V_c = velocity of contaminant (ft/yr)

V = velocity of groundwater (ft/yr)

b = bulk density of soil (grams per milliliter [g/mℓ])

n = soil porosity (unitless)

K_d = distribution coefficient, concentration of contaminant on the soil divided by concentration of contaminant in groundwater (mℓ/g)

This simple model does not consider the effects of longitudinal dispersivity resulting from aquifer heterogeneities.

In considering the maximum distance traveled by CCL4, the increased gradient (and hence groundwater flow rate) as one approaches the Wisconsin River must be recognized. Between wells SWN-91-03B and PBN-91-02B (along the flow-line near the center of the plume) the gradient is 0.0024 ft/ft, which results in an estimated groundwater flow velocity of 570 ft/yr (using the average K of $6.9\text{x}10^{-2}$ cm/sec from the aquifer test (see Section 6.0)). A weighted-average groundwater flow velocity for the Propellant Burning Ground, Settling Ponds and Spoils Disposal Area, and the off-post area south of BAAP is 440 ft/yr (Table 11-9). Soil bulk density (b) and soil porosity (n) are assumed to be 2 g/ml and 0.3, respectively.

Because site-specific K_ds are not available, these are estimated using the partition coefficients for the contaminants on carbon, K_{oc}, and the fraction of organic carbon (f_{oc}) in the soil. The relationship is as follows:

$$K_d = K_{oc} \cdot f_{oc}$$

where

K_{oc} = partition coefficient on carbon ($m\ell/g$)

f_{oc} = fraction of organic carbon in the soil (unitless)

Table 11-8 lists the values of K_{oc} available from literature for the major contaminants at BAAP. The f_{oc} for the aquifer soil is assumed to be 0.003. This is the average of the TOC data from nine subsurface soil samples collected from BGM-91-01, BGM-91-02, and BGM-91-03 (see Table 2-4).

CCL4 was reportedly first used at BAAP in 1942, and was disposed of at the Propellant Burning Ground. TRCLE was used at BAAP from 1966 to 1974 and was burned with lumber in the area of the three waste pits at the Propellant Burning Ground (USAEHA, 1985). According to the calculations in Table 11-9, CCL4 is expected to have traveled 6,875 feet in 50 years with a groundwater flow rate of 440 ft/yr. However, CCL4 has been detected in groundwater approximately 17,000 feet downgradient from the source area. This indicates that 440 ft/yr is a conservative groundwater flow rate for the 50-year period, or the K_d for CCL4 is too high, or longitudinal dispersivity plays a major role in contaminant transport. This model generally gives a conservative estimate of the retardation of chemicals moving through groundwater.

The examination of TRCLE transport provides insight into the transport of CCL4. Although the maximum distance that CCL4 has been transported is unknown, the distance traveled by TRCLE has been bracketed between wells SWN-91-03 and PBN-90-02, approximately 13,000 and 17,900 feet, respectively, from the probable source in the Contaminated Waste Area of the Propellant Burning Ground. We assume the TRCLE has been transported a minimum of 13,000 feet since it was reportedly first disposed of at BAAP in 1966, 26 years ago. The resulting V_c for TRCLE is 500 ft/yr, which is greater than the estimated maximum groundwater flow rate of 460 ft/yr (see Table 11-9 and Subsection 6.3.4). This, in effect, says that in the aquifer (for those chemicals whose behavior is governed by the organic carbon in soil), chemicals move freely with the groundwater.

We assume that CCL4 moves at the rate of groundwater (i.e., no retardation in the aquifer). The estimated distance traveled by CCL4 from the Propellant Burning Ground over 50 years is 22,000 feet, or 4.2 miles. This estimate places the leading edge of the CCL4 plume at, or beyond, the Wisconsin River. Based on concentrations observed at PBN-90-02D, if CCL4 has reached the Wisconsin River, the concentrations at the leading edge of the plume are probably below existing analytical certified reporting limits.

11.5 HUMAN HEALTH EVALUATION

Groundwater Quality Evaluation. Because federal and state standards exist for concentrations of compounds in groundwater, groundwater quality can be evaluated by direct comparison to the standards. The nature and distribution of contaminants in groundwater is fully described in Subsection 11.4. Compounds of potential concern are summarized in Table 11-10. In addition to the compound identity, the table provides the frequency of detection, the range of detected concentrations, and state and federal standards. CCL4 and NIT are detected at concentrations exceeding federal and state enforcement standards. As discussed in Subsection 11.4.2.2, NIT concentrations appear related to region-wide influences such as agricultural practices and not to a site-related NIT source. NA exceeds a federal reporting level and MN exceeds a secondary standard. CHCL3, CR, CD, PB, and TRCLE exceed WPALs, but are below the enforcement standards.

Earlier investigations identified several residential wells which were affected by BAAP contamination. An interim measure has replaced these water supplies with alternative sources. There is now no domestic use of water from this aquifer within the area known to be contaminated. However, the CCL4 plume which is present in the deeper portion of the sand and gravel aquifer south of the Propellant Burning Ground is a source of water for spray irrigation of crops. Consequently, a potential off-site exposure exists for the farm worker adjusting irrigation equipment to have some contact with this groundwater. This contact is assumed to be infrequent and of short duration, occurring during set-up and adjustment of the equipment. Because the exposure parameters are difficult to quantify, a way to estimate risk to the farm worker is to compare the nature of that exposure to risks calculated for a standard residential exposure to the same contaminants. It should be noted that this residential exposure does not occur at the present time nor is it expected to occur in the future; it is calculated to compare to a possible irrigation exposure only. These risks, calculated in Appendix O, Table O-92, are based on equations developed by USEPA (USEPA, 1991a) that assume an adult drinking two liters of water per day, as well as inhaling vapors from household sources (e.g., showering, laundering, dishwashing) for a residential duration of 350 days per year for 24 years. The total carcinogenic risk for ingestion and inhalation is $3x10^{-5}$, falling within the USEPA target range. The HI of 507 is well above the target level of 1.0 and is attributed entirely to ingestion of NIT and assigns the RfD of nitrite ($5x10^{-4}$) to NIT, as shown in version 1 on Table O-92 (Appendix O). If the nitrate RfD of 1.6 were used instead, as version 2 on Table O-92 (Appendix O) displays, the HI falls below 1.0. Based on these extremely conservative results for long-term, repetitive contact, it appears that a farm worker would incur no additional risk inasmuch as the worker is exposed only infrequently and then only through the inhalation route. The impact of these contaminants on the crops that are being irrigated is discussed in Subsection 11.6, Baseline Ecological Assessment, which concludes that it is unlikely that these compounds would concentrate in biota.

11.6 BASELINE ECOLOGICAL ASSESSMENT

Groundwater Quality Evaluation. Empirical data on the bioaccumulation potential of the various groundwater constituents detected in the off-facility monitoring wells (CCL4, CHCL3, and TRCLE) are limited, but there is no indication that these compounds would pose an environmental threat at the detected concentrations. Various studies report strong correlations between the tendency for compounds to bioconcentrate in biological tissue and the respective octanol:water partition coefficients (K_{ow}) (Veith et al., 1979). Empirical evidence suggests that food chain magnification is likely only for certain organic compounds, such as PCBs and dichlorodiphenyltrichloroethane (DDT), which have partition coefficients of 10^5 or greater (Rand and Petrocelli, 1985). Coefficients for the compounds detected in the groundwater plume are several orders of magnitude lower, ranging from $<10^0$ to 10^2. Consequently, it is not considered likely that these compounds would concentrate in biota.

11.7 CONCLUSIONS OF BASELINE HUMAN HEALTH AND ECOLOGICAL ASSESSMENTS

Based on the comparison of off-post groundwater south of BAAP to state and federal standards, remedial action objectives should be developed in the FS to reduce exposure to or contact with CCL4 in the groundwater.

12.0 SUMMARY AND CONCLUSIONS OF BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

12.1 SUMMARY OF BASELINE HUMAN HEALTH RISK ASSESSMENT

Baseline risk assessments were performed for 11 contaminated areas at BAAP and are presented in Sections 6 through 11 of the RI. The purpose of the baseline risk assessment was to evaluate potential risks to humans associated with exposure to contaminated media at each site. The evaluation of human health risks was conducted in accordance with current USEPA guidance. Exposure to soils, sediment, and surface water was evaluated quantitatively, while groundwater was evaluated qualitatively by comparing contaminant concentrations with applicable state and federal regulations or guidelines. The methods and associated uncertainties of the quantitative assessments, presented in detail in Section 4.0, are summarized in the following paragraphs.

Compounds of potential concern at each area were selected by applying four exclusion criteria to all compounds detected in media at the area. Compounds excluded were (1) those identified as laboratory or sampling contaminants; (2) inorganics that were not detected at concentrations greater than naturally occurring site-specific or regional background concentrations; (3) compounds detected in fewer than 5 percent of the samples of a single medium at a site; or (4) inorganics that are essential human nutrients and detected at concentrations that would result in a daily intake lower than the allowable daily intake for that nutrient. The exposure point concentration for compounds of potential concern is the maximum concentration in those instances where fewer than 20 samples of a given medium at a site were collected and the 95th percentile when 20 or more samples were available. The principal uncertainty involved with the selection of compounds of potential concern and respective exposure point concentrations is that degradation of compounds over time is not accounted for. This may lead to an overestimate of risk. The use of the maximum or 95th percentile concentration as an exposure point is also an overestimate of likely exposure.

Exposure scenarios were based on current and anticipated future land use at BAAP. Because BAAP is an industrial facility on standby status and is not scheduled for closure, it is assumed that future activity would be essentially the same as current activity. The receptors selected for evaluation were grounds maintenance worker, farmer, and construction worker. Incidental ingestion of soil and inhalation of particulates and vapors were the routes of exposure quantitatively assessed. Because absorption information was unavailable for the dermal route, it could not be evaluated. None of these scenarios evaluate a long-term, repetitive exposure to contaminated media nor do they provide a reasonable exposure scenario to contaminated sediment and surface water. Therefore, to provide a conservative, upper-bound comparison to the risks estimated from the more probable scenarios, a 30-year residential scenario was evaluated for all areas where surface soil data was available. Because it is recognized that future residential use is highly unlikely, the residential scenario will not be used to suggest remedial action. Exposure to sediment and surface water were evaluated for a child playing. To the extent possible, exposure factors were taken from USEPA guidance documents. The rationale and references for each exposure factor is given in Section 4.0.

The selection of exposure pathways and factors adds several levels of uncertainty to the assessment, the greater of which is that the pathway may never actually occur. The frequency, duration, and intensity of the exposure is based on many assumptions which may or may not reflect actual situations. An effort has been made to employ conservative but not unrealistic values so that the effect of the uncertainty is more likely to overestimate the risk. However, the inability to evaluate the dermal route of exposure underestimates risk to an unknown degree.

The toxicity assessment is based on quantitative cancer slope factors and reference doses published in the IRIS or HEAST. Certain COCs without toxicity values were evaluated qualitatively when information was available. Reference concentrations for noncarcinogenic effects by the inhalation route were not available for most COCs, so inhalation routes could not be fully quantified. Dermal toxicity values also are not available, so oral values were used as surrogates for dermal exposure to surface water. Surrogate values were also used in the evaluation of PAHs where the values for BAPYR and NAP were used to evaluate carcinogenic and noncarcinogenic risks respectively. Because USEPA has not published dose-response values for PB, a quantitative assessment was not possible. Rather, soil concentrations of PB were evaluated by comparison to the soil cleanup levels established by USEPA in an interim guidance document (USEPA, 1989c). Uncertainties involved with the use of toxicity values include the extrapolation of high-dose, animal data to humans and the use of a non-threshold, linear model to derive CSFs, both of which probably overestimate risk. Lack of toxicity values for some compounds and routes results in an underestimate of risk. The use of surrogates has an unknown effect.

Risk characterization involves developing lifetime incremental cancer risks and hazard quotients for each chemical. Within each exposure pathway, cancer risks or hazard quotients were summed to yield a pathway-specific cancer risk or HI. In some cases pathways were summed to characterize populations exposed by multiple routes of exposure. The risk estimates were then compared to target levels established by USEPA: for carcinogens, a range of 10^{-6} to 10^{-4}, and for noncarcinogens an HI of 1.0. The main uncertainty introduced by the risk characterization process is the assumption that effects from exposure to multiple substances are additive. The effects, instead, are likely to be more complex and involve synergistic or antagonistic effects between certain compounds. Whether this results in an over- or underestimate of risk is unknown.

Using the most probable scenarios (i.e., grounds maintenance worker, farmer, and construction worker) for calculating risk, the baseline risk assessment conducted for BAAP indicates that no significant health risks would be expected from exposure to soil at any of the 11 areas, with the exception of subsurface soil at the Deterrent Burning Ground. This is corroborated for the most part by the conservative evaluation of risk for a future resident. The only areas where quantitative assessment indicated risks above target levels for a residential scenario is at Settling Pond 1 and the Rocket Paste Area. Estimates of a child's risk from exposure to surface water and sediments also did not exceed target levels. The qualitative evaluation of PB, however, indicates that concentrations in soil at the Propellant Burning Ground, Nitroglycerine Pond, Rocket Paste Area, and Old Acid Area exceed the interim cleanup level, as does the concentration of PB in sediment at the Rocket Paste Area. The qualitative evaluation of groundwater shows that COCs in groundwater at the following areas exceed state and/or federal standards: Propellant Burning Ground/Settling Ponds, Deterrent Burning Ground/Existing Landfill, and Off-Post wells south of BAAP. The presence of contaminants above their respective standards indicates a potential risk to human health.

The ultimate use of the baseline risk assessment is to support the development of remedial action objectives for areas where the assessment has determined that a potential human health risk exists. The areas for which remedial action objectives are recommended to protect human health are listed in Subsection 12.3.

12.2 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

The BAAP Baseline Environmental Assessment:

- provides a characterization of the ecological resources and habitats at BAAP
- identifies those ecological habitats which may be located within pathways of contamination
- identifies the types of fish and wildlife receptors which may be exposed to site-related constituents
- evaluates the potential toxicological effects expected from site contamination
- identifies the uncertainties inherent in the risk characterization process and highlights those assumptions that most significantly affected the assessment process

The environmental media evaluated in the baseline ecological assessment for BAAP include surface soil, surface water, and sediment. Based on a screening of detected concentrations with biological effect levels, a subset of the constituents detected in these three media have been considered as COCs for this ecological assessment. Although site-related contamination has also been detected in groundwater and sub-surface soils, no ecological exposure to sub-surface soils is anticipated, and groundwater exposure concentrations in off-site areas associated with irrigation activities are well below levels associated with ecological impacts.

Exposure pathways considered in the ecological assessment were chosen based on the characteristics of ecological receptors and communities at the site, the physical and chemical properties of the COCs, and the affected environmental media at BAAP. Exposure pathways for aquatic receptors included dermal contact, ingestion of contaminated surface water and sediment, and the consumption of contaminated prey items. Terrestrial receptors at BAAP may be exposed to surface soil contaminants through the incidental ingestion of soil, dermal contact, and the consumption of contaminated prey items. In addition, terrestrial and semi-aquatic receptors may be exposed to contaminants in surface water and sediment via the water consumption, consumption of contaminated prey, incidental sediment ingestion, and dermal contact pathways.

Potential exposures to aquatic receptors were evaluated by comparing maximum detected contaminant concentrations in surface water and sediment to applicable state and federal criteria and guidelines. Potential exposures by aquatic organisms associated with the prey consumption pathway was not evaluated due to a lack of ingestion toxicity data for these receptors. However, potential exposures to terrestrial ecological receptors via the consumption of contaminated prey items and the incidental soil ingestion pathways were evaluated via computer food web modeling. Drinking water and consumption of contaminated aquatic prey items was evaluated by comparing exposure point concentrations to derived Wisconsin Wildlife and Domestic Animal Criteria.

Comparison of the contaminant concentrations detected in the surface water and sediment at BAAP with state and federal toxicological criteria and guidelines indicate that aquatic life may be adversely effected from chronic exposure to contaminated surface water and sediment at the Rocket Paste Pond and the Nitroglycerine Pond. It is not anticipated that aquatic organisms exposed to Ballistics Pond surface water would be adversely impacted, however. Maximum detected concentrations of the following surface water contaminants at either the Rocket Paste Pond or the Nitroglycerine Pond exceed state or federal water quality criteria or guidelines for a number of inorganic constituents. Those COCs with the highest HQs, and hence the greatest likelihood to adversely impact aquatic biota include the following:

- Rocket Paste Pond - AL, CU, FE, and PB
- Nitroglycerine Pond - FE, HG, and PB

Of these, PB and HG are known to bioconcentrate in plant and animal tissues and thus may become available to higher trophic level species.

No federal or state criteria are available to evaluate the potential toxicity of the COCs detected in sediment samples collected at BAAP. However, toxicological guidelines and screening values for certain inorganic compounds and nutrients were used where available. Maximum concentrations of the inorganic sediment contaminants appear to be of sufficient magnitude as to result in adverse effects on a variety of aquatic species. The maximum PB concentrations detected at the Rocket Paste Pond and the Nitroglycerine Pond were found to exceed the guideline value for this contaminant; HG was also predicted to be adversely impacting aquatic receptors exposed to Nitroglycerine Pond sediment. As with surface water exposures, both of these COCs have the potential to become incorporated into ecological food webs, as well.

Risks to terrestrial receptors at BAAP were evaluated through food chain computer modeling, and risks were quantitatively evaluated using a HI ranking scheme. The results of the BAAP terrestrial wildlife food chain models suggest that small mammals and birds are likely being exposed to contaminant concentrations considerable greater than levels shown to produce adverse effects under laboratory conditions. Higher trophic level consumers were also predicted to be at risk if they were to forage regularly in contaminated habitats at BAAP.

PB and SN, and to a lesser extent ZN, were determined to be the most significant risk contributors for the majority of modeled ecological receptor species. Surface soil concentration of PB, in particular, was determined to be resulting in significant risk levels at most of the study areas evaluated, including the Propellant Burning Ground, Settling Ponds/Spoils Disposal Area, Nitroglycerine Pond Area, Rocket Paste Area, and the Old Acid Area. Minimal or no risks are anticipated for ecological exposures at the Deterrent Burning Ground/Existing Landfill Area, New Acid Area, Oleum Plant, and the Old Fuel Oil Tank Area.

The estimated exposure concentrations/dosages and toxicological effects associated with a given exposure (from which these risk conclusions were derived) are based on a number of simplifying assumptions and involve various risk uncertainties. As appropriate in a baseline assessment, a conservative approach was used throughout to quantitate uncertainties associated with the magnitude of exposures and toxicological effects. However, in some cases, this approach may have resulted in overly conservative measure of potential risk. The following issues appear to have most significantly affected the risk conclusions:

- Effects to individual receptors were evaluated in this baseline assessment and a focus on impacts to ecological populations, or even the overall community, may be more appropriate if no species of special concern occur at BAAP. Information to address this issue should be available following the plant and animal survey to be conducted at BAAP in 1993.

- Maximum detected concentrations of COCs detected in surface water and sediment were used to quantify exposure point concentrations for aquatic receptors. This assumption provides an upper bound to potential exposures and risk, but maximum detected concentrations are probably not representative of typical conditions experienced by most receptors.

- Uptake and bioaccumulation factors were conservatively estimated to evaluate surface soil exposures, and the derived exposure doses may be overestimates of actual conditions as a result. This is reflected in the finding of ecological risks associated with certain inorganic COCs within the range of naturally-occurring background concentrations. Of particular question is the actual bioavailability of inorganic COCs such as PB to different terrestrial receptor species. Although little information is available in the literature to address this concern, field studies designed to assess the bioavailability of surface soil constituents would be extremely useful in developing a more accurate characterization of potential risks that terrestrial receptors experience at BAAP.

12.3 CONCLUSIONS

The human health and ecological risk assessments presented in Sections 6 through 11 evaluate potential risks associated with exposure to contaminated media at each SWMU. Based on the results of the risk assessments, remedial action objectives to eliminate, reduce or control risks from contaminated media are indicated at certain sites. Table 12-1 summarizes the site, media, and contaminants of concern for which remedial action objectives should be developed as part of the FS. The table also indicates whether the contaminants of concern in a particular medium are a source of risk to human or ecological receptors.

Media and areas for which the baseline risk assessments conclude that remedial action objectives are not warranted are:

- groundwater at the Rocket Paste Area, Nitroglycerine Pond, and New Acid Area
- surface and subsurface soil at the Oleum Plant and Oleum Plant Pond
- sediment at the Oleum Plant and Oleum Plant Pond
- sediment at the Ballistics Pond
- surface water at the Ballistics Pond
- groundwater at the Oleum Plant and Ballistics Pond Area
- surface and subsurface soil at the Old Acid Area
- subsurface soil at the Old Fuel Oil Tank Area
- groundwater at the Old Acid Area and Old Fuel Oil Tank Area

USATHAMA CHEMICAL CODES

cis-1,2-dichloroethene	C12DCE
cobalt	CO
copper	CU
cyclonite	RDX
cyclopentanone	CPO
cyclotetramethylenetetranitramine	HMX
dibenzo(a,h)anthracene	DBAHA
diethyl ether	DEETH
diethyl phthalate	DEP
dimethyl phthalate	DMP
di-n-butyl phthalate	DNBP
dinitrobenzene	DNB
dinitrophenol	DNP
di-n-octyl phthalate	DNOP
diphenylamine	DPA
ethylbenzene	ETC6H5
fluoranthene	FANT
fluorene	FLRENE
hydrogen sulfate	H2SO4
indeno(1,2,3-cd)pyrene	ICDPYR
iron	FE
lead	PB
magnesium	MG
manganese	MN
mercury	HG
methylene chloride	CH2CL2
methyl ethyl ketone or 2-butanone	MEK
methylisobutyl ketone	MIBK
naphthalene	NAP
n-butyl ether	NBUETH
nitroaniline	NANIL

nickel	NI
nitrate	NO3
nitrite	NO2
nitrite/nitrate-nonspecific	NIT
nitrobenzene	NB
nitrocellulose	NC
nitrogen	N
nitrogen by Kjeldahl Method	N2KJEL
nitroglycerine	NG
nitrosodi-n-propylamine	NDNPA
n-nitrosodimethylamine	NNDMEA
n-nitrosodi-n-propylamine	NNDNPA
n-nitrosodiphenylamine	NNDPA
nitrotoluene	NT
phenanthrene	PHANTR
phenol	PHENOL
phthalates	PHTHL
polynuclear aromatic hydrocarbon	PAH
potassium	K
pyrene	PYR
selenium	SE
silver	AG
sodium	NA
styrene	STYR
sulfate	SO4
tetrachloroethylene	TCLEE
thallium	TL
tin	SN
toluene	MEC6H5
total dissolved solids	TDS
total hardness	HARD
total organic carbon	TOC
total organic halogens	TOX
trans-1,2-dichloroethene	T12DCE
trans-1,3-dichloropropene	T13DCP
trichloroethylene	TRCLE

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USATHAMA CHEMICAL CODES

trichlorofluoromethane	CCL3F
trimethylbenzenes	TRIMBZ
trinitrotoluene	TNT
vanadium	V
vinyl acetate	C2AVE
vinyl chloride	C2H3C
xylene	BTEX
xylene	XYLEN
xylenes, total combined	TXYLEN
zinc	ZN
1,1-dichloroethane	11DCLE
1,1-dichloroethylene	11DCE
1,1,1-trichloroethane	111TCE
1,1,2-trichloroethane	112TCE
1,2-dichloroethane	12DCLE
1,2-dichloroethylene	12DCE
1,2-dimethylbenzene/o-xylene	12DMB
1,2,3-propadetriol diacetate	123PDA
1,3-dichlorobenzene	13DCLB
1,3-dimethylbenzene	13DMB
1,4-dichlorobenzene	14DCLB
2-butanone or methyl ethyl ketone	MEK
2-butoxyethanol	2BUXEL
2-ethyl-1-hexanol	2E1HXL
2-methylnaphthalene	2MNAP
2-nitroaniline	2NANIL
2-nitro-n-nitrosodiphenylamine	2NNDPA
2-nitrotoluene	2NT
2,3,6-trimethylnaphthalene	236TMN
2,4-dinitrotoluene	24DNT
2,4,6-trinitrotoluene	246TNT
2,6-dinitrotoluene	26DNT
3-nitrotoluene	3NT
3,5-dinitrotoluene	35DNT
4-nitroaniline	4NANIL
4-ethyl-2-methylhexane	4E2MHX

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) DESCRIPTIONS

GW	Well-graded gravels, gravel-sand mixtures, little or no fines
GP	Pooorly-graded gravels, gravel-sand mixtures, little or no fines
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SW	Well-graded sands, gravelly sands, little or no fines
SP	Poorly-graded sands, gravelly sands, little or no fines
SM	Silty-sands, sand-silt mixture
SC	Clayey-sands, sand-clay mixture
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
OL	Organic silts and organic silty clays of low plasticity
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts
Pt	Peat and other highly organic soils

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3NT	3-nitrotoluene
4NANIL	4-nitroaniline
4E2MHX	4-ethyl-2-methylhexane

LISTED BY ANALYTE NAME

acenaphthene	ANAPNE
acenaphthylene	ANAPYL
acetone	ACET
acrylonitrile	ACRYLO
alkalinity	ALK
alkane	ALKN
aluminum	AL
ammonia	NH3
ammonia nitrogen	NH3N2
anthracene	ANTRC
antimony	SB
arsenic	AS
barium	BA
benzene	C6H6
benzo(a)anthracene	BAANTR
benzo(a)pyrene	BAPYR
benzo(b)fluoranthene	BBFANT
benzo(g,h,i)perylene	BGHIPY
benzoic acid	BENZOA
benzo(k)fluoranthene	BKFANT
benzothiazole	BTA
benzyl alcohol	BZALC
beryllium	BE
bis(2-ethylhexyl)phthalate	B2EHP
bromide	BR
butylbenzylphthalate	BBZP
cadmium	CD
calcium	CA
calcium sulfate salt	CASO4
carbon tetrachloride	CCL4
chloride	CL
chloroform	CHCL3
chloromethane	CH3CL
chromium	CR
chrysene	CHRY

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MN	manganese
N	nitrogen
NA	sodium
NANIL	nitroaniline
NAP	naphthalene
NB	nitrobenzene
NBUETH	n-butyl ether
NC	nitrocellulose
NDNPA	nitrosodi-n-propylamine
NG	nitroglycerine
NH3	ammonia
NH3N2	ammonia nitrogen
NI	nickel
NIT	nitrite/nitrate-nonspecific
NNDMEA	n-nitrosodimethylamine
NNDNPA	n-nitrosodi-n-propylamine
NNDPA	n-nitrosodiphenylamine
NO2	nitrite
NO3	nitrate
NT	nitrotoluene
N2KJEL	nitrogen by Kjeldahl Method
PAH	polynuclear aromatic hydrocarbon
PB	lead
PHANTR	phenanthrene
PHENOL	phenol
PHTHL	phthalates
PYR	pyrene
RDX	cyclonite
SB	antimony
SE	selenium
SN	tin
SO4	sulfate
STYR	styrene
TCLEE	tetrachloroethylene

USATHAMA CHEMICAL CODES

TDS	total dissolved solids
TL	thallium
TNT	trinitrotoluene
TOC	total organic carbon
TOX	total organic halogens
TRCLE	trichloroethylene
TRIMBZ	trimethylbenzenes
TXYLEN	xylenes, total combined
T12DCE	trans-1,2-dichloroethene
T13DCP	trans-1,3-dichloropropene
V	vanadium
XYLEN	xylene
ZN	zinc
11DCE	1,1-dichloroethylene
11DCLE	1,1-dichloroethane
111TCE	1,1,1-trichloroethane
112TCE	1,1,2-trichloroethane
12DCE	1,2-dichloroethylene
12DCLE	1,2-dichloroethane
12DMB	1,2-dimethylbenzene/o-xylene
123PDA	1,2,3-propadetriol diacetate
13DCLB	1,3-dichlorobenzene
13DMB	1,3-dimethylbenzene
14DCLB	1,4-dichlorobenzene
2BUXEL	2-butoxyethanol
2E1HXL	2-ethyl-1-hexanol
2MNAP	2-methylnaphthalene
2NANIL	2-nitroaniline
2NNDPA	2-nitro-n-nitrosodiphenylamine
2NT	2-nitrotoluene
236TMN	2,3,6-trimethylnaphthalene
24DNT	2,4-dinitrotoluene
246TNT	2,4,6-trinitrotoluene
26DNT	2,6-dinitrotoluene
35DNT	3,5-dinitrotoluene

LISTED BY ANALYTE ACRONYM

ACET	acetone
ACRYLO	acrylonitrile
AG	silver
AL	aluminum
ALK	alkalinity
ALKN	alkane
ANAPNE	acenaphthene
ANAPYL	acenaphthylene
ANTRC	anthracene
AS	arsenic
BA	barium
BAANTR	benzo(a)anthracene
BAPYR	benzo(a)pyrene
BBFANT	benzo(b)fluoranthene
BBZP	butylbenzylphthalate
BE	beryllium
BENZOA	benzoic acid
BGHIPY	benzo(g,h,i)perylene
BKFANT	benzo(k)fluoranthene
BR	bromide
BTA	benzothiazole
BTEX	xylene
BZALC	benzyl alcohol
B2EHP	bis(2-ethylhexyl)phthalate
CA	calcium
CASO4	calcium sulfate salt
CCL3F	trichlorofluoromethane
CCL4	carbon tetrachloride
CD	cadmium
CHCL3	chloroform
CH2CL2	methylene chloride
CH3CL	chloromethane
CHRY	chrysene
CL	chloride
CO	cobalt

USATHAMA CHEMICAL CODES

CPO	cyclopentanone
CR	chromium
CU	copper
C2AVE	vinyl acetate
C2H3CL	vinyl chloride
C6H6	benzene
C12DCE	cis-1,2-dichloroethene
DBAHA	dibenzo(a,h)anthracene
DEETH	diethyl ether
DEP	diethylphthalate
DMP	dimethylphthalate
DNB	dinitrobenzene
DNBP	di-n-butyl phthalate
DNOP	di-n-octyl phthalate
DNP	dinitrophenol
DPA	diphenylamine
ETC6H5	ethylbenzene
FANT	fluoranthene
FE	iron
FLRENE	fluorene
HARD	total hardness
HG	mercury
HMX	cyclotetramethylenetetranitramine
H2SO4	hydrogen sulfate
ICDPYR	indeno(1,2,3-cd)pyrene
K	potassium
MEC6H5	toluene
MEK	methyl ethyl ketone or 2-butanone
MEK	2-butanone or methyl ethyl ketone
MG	magnesium
MIBK	methylisobutyl ketone

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAS	atomic absorption spectrophotometry
ABB-ES	ABB Environmental Services, Inc.
ABS	chemical-specific absorption fraction
AFo	oral absorption fraction
AIS	Acceptable intake-subchronic
AMC COM	Armament munitions and chemical compound
ARAR	Applicable or Relevant and Appropriate Requirement
ARF	analytical request form
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAAP	Badger Army Ammunition Plant
BAF	bioaccumulation factor
BCF	bioconcentration factor
BCW	Boundary Control Well
bgs	below ground surface
BN/A	base neutral and acid extractable organics
BOD	biochemical oxygen demand
BW	body weight
CAA	Clean Air Act
CAAA	Clean Air Act Amendment
CAG	Carcinogen Assessment Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund statute)
CF	conversion factor
CLASS	Contract Laboratory Analytical Services Support
CLP	Contract Laboratory Program
CMS	Corrective Measures Study
cm/hr	centimeters per hour
cm/sec	centimeters per second
COC	chemical of concern
COD	chemical oxygen demand
CRL	certified reporting limit
CSF	carcinogen slope factor
CWA	Clean Water Act
DCE	dichloroethylene

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

DDT	dichlorodiphenyl trichloroethene
DI	daily intake
DNAPL	dense nonaqueous phase liquid
DNT	dinitrotoluene
EA	Environmental Assessment
ECD	electron capture detection
ED	exposure duration
EEI	Envirodyne Engineers, Inc.
EF	exposure frequency
EM	electromagnetic
EP	Extraction Procedure
EPTOX	Extraction Procedure Toxicity
ERA	ecological risk asessment
ESE	Environmental Sciences and Engineering, Inc.
FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FS	feasibility study
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
FUDs	formerly used defense sites
GC	gas chromatography
g/mℓ	grams per milliliter
GHB	general-head boundary
GOCO	government-owned, contractor-operated
gpm	gallons per minute
GPR	ground-penetrating radar
HAPs	hazardous air pollutants
HAS	health advisories
HASP	Health and Safety Plan
HEA	health effects assessment
HEAST	Health Effects Assessment Summary Table
HI	Hazard Index
HIF	human intake factor
HPLC	High Performance Liquid Chromatography

HQ	hazard quotient
HSA	hollow-stem auger
HSDB	Hazardous Substance Databank
HSL	Hazardous Substance List
HSWA	Hazardous and Solid Waste Act
ICP	inductively coupled plasma
ID	inside diameter
in/yr	inches per year
IR	ingestion rate
IRIS	Integrated Risk Information System
IRDMIS	Installation Restoration Data Management Information System
IRM	Interim Remedial Measure
IRP	Installation Restoration Program
IUBK	integrated uptake/biokinetic
kg	kilogram
kg/m^3	kilograms per cubic meter
km/hour	kilometers per hour
LD_{50}	single dosage lethal to 50 percent of test organisms
LMS	linearized multistage
LNAPL	light nonaqueous phase liquid
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Observed Effect Level
LT	less than
m	meter
m^2	meters squared
m^3	meters cubed
MACT	maximum achievable control technology
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MEP	Master Environmental Plan
m^3/hour	cubic meters per hour
mg/cm^2	milligrams per square centimeter
mgd	million gallons per day
mg/day	milligrams per day
mg/kg	milligrams per kilogram

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

mg/m^3	milligrams per cubic meter
mg/ℓ	milligrams per liter
mgN/ℓ	milligrams per liter expressed as nitrogen
mℓ	milliliter
mℓ/g	milliliters per gram
MODFLOW	Modular Three-Dimensional Finite Difference Groundwater Flow Model
MRL	minimum risk level
MS	mass spectrometry
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
NAC/SAC	Nitric Acid/Sulfuric Acid Concentration
NAM	nitrosamine
NCP	National Contingency Plan
ND	non-detect
NEPA	National Environmental Protection Agency
NERI	Northeast Research Institute, Inc.
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NPD	nitrogen phosphorus detector
NPL	National Priorities List
NSPS	new source performance standards
OD	outside diameter
PAH	polynuclear aromatic hydrocarbon
PbB	blood lead level
PCB	polychlorinated biphenyl
PDE	potential dietary exposure
PEF	particulate emission factor
PHE	Public Health Evaluation
PID	photoionization detector
PM10	concentrations of respirable dust particles
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PSD	prevention of significant deterioration

psi	pounds per square inch
PVC	polyvinyl chloride
QA	Quality Assurance
QC	Quality Control
RAF	relative adsorption factor
RAGs	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RDA	recommended dietary allowance
RfC	inhalation reference concentration
RfD	reference dose
RFI	RCRA Facility Investigation
RI	remedial investigation
RL	regulatory level
RPA	Rocket Paste Area
RTV	Reference Toxicity Value
SAR	Sulfuric Acid Recovery
SARA	Superfund Amendments and Reauthorization Act
SCW	Source Control Well
SDWA	Safe Drinking Water Act
SF	slope factor
sff	site foraging frequency
SIP	State Implementation Plan
SPHEM	Superfund Public Health Evaluation Manual
SQC	Sediment Quality Criteria
SVOC	semivolatile organic compound
s.u.	standard units
SWMU	solid waste management unit
TAL	Target Analyte List
TBC	to be considered
TBD	total body dose
TC	terrain conductivity
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TPHC	total petroleum hydrocarbons
TSD	treatment, storage, or disposal

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

TV	threshold value
$\mu g/g$	micrograms per gram
ug/gC	μg contaminant per gram of organic carbon
$\mu g/\ell$	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
μm	micrometers
μmhos/cm	micromhos per centimeter
USACE	U.S. Army Corps of Engineers
USAEHA	U.S. Army Environmental Hygiene Agency
USAMC	U.S. Army Materiel Command
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USF&WS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VOC	volatile organic compound
WAC	Wisconsin Administrative Code
WBER	Wisconsin Bureau of Endangered Resources
WDAC	Wildlife and Domestic Animal Criterion
WDAV	Wildlife and Domestic Animal Value
WDNR	Wisconsin Department of Natural Resources
WES	Wisconsin Enforcement Standard
WGQS	Wisconsin Groundwater Quality Standard
WPAL	Wisconsin Preventive Action Limit
WP&L	Wisconsin Power and Light
WQC	Water Quality Criteria
WWTP	wastewater treatment plant
XBAR	average percent recovery