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Record of Decision:

DOVER AIR FORCE BASE
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DOVER, DE
01/26/2006

RECORD OF DECISION FOR
SITES WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, AND AREA 6
WEST MANAGEMENT UNIT
DOVER AIR FORCE BASE, DELAWARE

January 2006

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LIST OF ACRONYMS AND ABBREVIATIONS

AAB	Accelerated anaerobic biodegradation
AAS/SVE	Aquifer air sparging/soil vapor extraction
AFI	Air Force Instruction
AMC	Air Mobility Command
ARAR	Applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	Below ground surface
CDI	Chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of concern
COPC	Contaminant of potential concern
DAFB	Dover Air Force Base
DCA	Dichloroethane
DCE	Dichloroethene
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DNREC	Department of Natural Resources and Environmental Control
DRGCAP	Delaware Regulations Governing the Control of Air Pollution
DRGHW	Delaware Regulations Governing Hazardous Waste
EECA	Engineering Evaluation and Cost Analysis
EPC	Exposure point concentration
ERA	Ecological Risk Assessment
ERP	Environmental Restoration Program
FFA	Federal Facilities Agreement
FS	Feasibility Study
ft	Feet
GAC	Granulated activated carbon
GMZ	Groundwater management zone
GRW	Groundwater recirculation well
HAZWRAP	Hazardous Waste Remedial Actions Program
HEAST	Health Effects Assessment Summary Tables
HI	Hazard index
HQ	Hazard quotient
HRC	Hydrogen Release Compound™
HSCA	Hazardous Substance Cleanup Act
IRIS	Integrated Risk Information System
IWCD	Industrial waste collection drain
LECR	Lifetime excess cancer risk
LOAEL	Lowest observed adverse effect level
LUCs	Land use controls

LIST OF ACRONYMS AND ABBREVIATIONS (cont'd)

µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
$\mu g/m^3$	Micrograms per cubic meter
MCL	Maximum contaminant level
MOA	Memorandum of Agreement
mg/kg-day	Milligrams per kilogram-day
MRL	Minimal risk level
msl	Mean sea level
NCP	National Contingency Plan
NPL	National Priorities List
NQR	No quantifiable risk
O&M	Operation and maintenance
PCE	Tetrachloroethene
ppb	Parts per billion
PRB	Permeable reactive barrier
RAO	Remedial action objective
RBC	Risk-based concentration
RBSC	Risk-based screening criterion
RCRA	Resource Conservation and Recovery Act
RfD	Reference dose
RI	Remedial Investigation
ROC	Receptor of concern
ROD	Record of Decision
RTDF	Remediation Technologies Development Forum
SAIC	Science Applications International Corporation
SARA	Superfund Amendments and Reauthorization Act
SF	Slope factor
SLERA	Screening Level ERA
SSL_{gw}	USEPA Soil Screening Levels for Transfers from Soil to Groundwater
TA	Target Area
TCA	Trichloroethane
TCE	Trichloroethene
TRV	Toxicity reference value
TSV	Toxicity screening value
UCL	Upper confidence limit
UF	Uncertainty factor
UIC	Underground injection control
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USEPA	U.S. Environmental Protection Agency
UST	Underground storage tank
UVB	Unterdruck-Verdampfer-Brunnen (Groundwater Recirculation Wells)
VOC	Volatile organic compound
WMU	West Management Unit

PART I: DECLARATION

1.0 SITE NAMES AND LOCATION

Sites: WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, and Area 6
West Management Unit
Dover Air Force Base
Kent County, Delaware
CERCLIS ID: DE8570024010

1.1 STATEMENT OF BASIS AND PURPOSE

This Record of Decision (ROD) presents the selected remedy for seven sites (WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28) and an associated groundwater contaminant plume known as Area 6 in the West Management Unit (WMU) at Dover Air Force Base (DAFB or Base) in Kent County, Delaware. The U.S. Air Force (USAF), as the lead agency for Superfund activities at DAFB, has prepared this ROD to fulfill the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) 42 USC § 9601 *et seq.*, and the National Oil and Hazardous Substances Pollution Contingency Plan, 40 Code of Federal Regulations (CFR) Part 300 (National Contingency Plan [NCP]). This decision is based on the Administrative Record for Area 6 and associated sites.

The USAF and U.S. Environmental Protection Agency (USEPA), Region 3 have made the final remedy selection for the sites addressed in this ROD. The State of Delaware, through the Department of Natural Resources and Environmental Control (DNREC) Division of Air and Waste Management, concurs with the selected remedy.

1.2 ASSESSMENT OF SITES

The seven sites addressed in this ROD are:

- WP21 - former unlined wastewater lagoons in operation from 1963 to 1986, and former concrete wastewater basins in operation until 1998;
- WP31 - two former underground storage tanks (USTs) that were removed in 1989. Mixed petroleum and solvent contamination is present at this site;
- ST34 - former fuel oil UST next to maintenance buildings removed in 1987. Mixed petroleum and solvent contamination is present at this site;
- OT41/Bldg. 719 – a portion of the former industrial waste collection drain [IWCD], expanded to include a former degreasing operation at Building 719;
- OT48 - two oil/water separators at Building 711, an avionics maintenance facility, installed in 1969 and still in operation;

- SS59 – an open storage area used for storing various materials (also called the Paint Washout Area and Lindane Source Area); and
- OT28 – a former wastewater treatment plant that had processed both sanitary and industrial wastewater during its operation, until its closure in 1975.

During the Remedial Investigation (RI) for the WMU, soil, groundwater, surface water, and sediment were investigated as applicable, and ecological and human health risks from exposure to contaminants were evaluated for all seven sites and the Area 6 plume as a whole. The RI and risk assessments determined the following:

- There are no source materials constituting principal threat wastes at five of the seven sites (WP21, WP31, ST34, OT48, and OT28). At two of the sites, OT41/Bldg. 719 and SS59, source materials were identified that could have posed a continuing threat to groundwater. Interim actions were taken at both of these sites to mitigate the threat. At OT41/Bldg. 719, an accelerated anaerobic biodegradation (AAB) system was constructed and is currently operating to address the source of chlorinated volatile organic compounds (VOCs) underneath Building 719. At pesticide spill site SS59, a pesticide soil source was removed and an asphalt capping system was installed. These two actions are further discussed in Sections 2.3, 2.8.1.9, and 2.8.1.10.

- As a result of past industrial activities at all seven sites, releases of VOCs and Lindane (a pesticide) have contaminated the groundwater in the surficial aquifer (Columbia Aquifer). The commingling groundwater contaminants from all seven sites form a single large plume called Area 6.

- There are no ecological risks associated with any of the WMU sites.

- There are no unacceptable risks associated with the surface water or sediment media at any of the seven sites.

- For the soil medium, past actions have been taken at five of the seven sites (WP21, ST34, WP31, OT41/Bldg. 719, and SS59) as further discussed in Sections 2.1 and 2.3. Risks to human health from soil were evaluated assuming commercial/industrial uses (such as utility or maintenance work) at all seven sites. Residential uses were also evaluated at the one site (OT28) because it is located in the Base housing area. The risk assessment identified no exceedances of federal or state risk criteria for the soil medium at any of the seven sites that would require further action, as long as land use remains consistent with the scenarios used to evaluate the sites, and the asphalt cover system at SS59 remains in place. For soil at site OT28, no unacceptable risks were identified based on residential scenarios; consequently, no further action is required for soil at OT28.

- For groundwater, risks to human health were evaluated assuming commercial/industrial uses at all seven sites and for the overall Area 6 groundwater plume. Residential uses of groundwater were also evaluated at

OT28. Based on the risk assessment, which is discussed in greater detail in Section 2.6 of this ROD, groundwater contamination resulted in risks exceeding federal comparison criteria under commercial/industrial scenarios at all sites except OT28. For groundwater at OT28, risks for the hypothetical residential scenario exceeded the federal criteria.

- Federal Safe Drinking Water Act maximum contaminant levels (MCLs) were exceeded in the Columbia Aquifer at all seven sites. There are residential, industrial, and agricultural users of the Columbia Aquifer within the surrounding community. Because the Columbia Aquifer is a currently used drinking water source, MCL exceedances at all seven sites and the Area 6 plume trigger the need for action.

Therefore, based on the RI and risk assessment, action is required to address groundwater contamination at all seven of the sites and the Area 6 plume as a whole. Additionally, action is required to ensure that land use at Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and within Area 6, remains consistent with the commercial/industrial land use scenarios used to assess the sites. The response action selected in this ROD is necessary to protect the public health or welfare from actual releases of hazardous substances into the environment at Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, and Area 6.

1.3 DESCRIPTION OF SELECTED REMEDY

Overall Strategy: Since its listing on the Superfund National Priorities List (NPL) in March 1989, DAFB has conducted a Basewide RI and Feasibility Studies (FSs) under the Air Force Environmental Restoration Program (ERP). As part of the overall site cleanup strategy for the Base, DAFB was divided into four management units for the purpose of conducting these studies. The WMU is one of these four management units. The seven sites being addressed in this ROD are all located within the WMU. DAFB's general strategy for addressing contaminant release sites is to group sites within their associated groundwater plumes and address cleanup requirements by plume. Thus, the Area 6 plume and its seven associated release sites are being addressed as one operable unit in one final ROD. Several interim actions have previously been conducted at sites within the Area 6 plume, including:

- Soil removal and capping at the Site WP21 industrial waste lagoons;
- Four underground storage tank removals – one at ST34, two at WP31, and one at OT41/Bldg. 719;
- Co-metabolic bio-venting to treat soil contamination at Site OT41/Bldg. 719;
- Soil removal, treatment, and off-site disposal at Site WP21 concrete waste basins;
- Soil removal, treatment, and off-site disposal at Site SS59, and installation of an asphalt capping system;

- AAB to treat groundwater contamination and residual soil contamination at OT41/Bldg. 719;
- Natural Attenuation with Monitoring to address groundwater contamination within Area 6, including RCRA post-closure monitoring at WP21.

This ROD selects the final remedy for all media at the seven sites (WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28), and addresses groundwater contamination within the entire Area 6 plume.

Principal Threat Wastes: Source materials that constitute principal threats may still be present at one of the Area 6 sites: OT41/Bldg. 719. This site is the single largest contributor of contaminants to the Area 6 plume. Solvents (chlorinated VOCs) from a former degreasing operation are present underneath Building 719, which is an active aircraft engine maintenance facility. The degreasing operation ceased during the early 1970s. Solvents from the former degreasing operation are believed to have been released into the ground through leaking pipes underneath the building. Based on the subsurface data collected below the building's foundation, it is likely that the release of solvents passed quickly through the gravel sub-base and into the zone of soil affected by the natural fluctuations of the water table. The AAB treatment system, described in Sections 2.3 and 2.8.1.9, was installed as an interim remedy at OT41/Bldg. 719 to address this source of contamination. Data from the site indicates that as the water table fluctuates up and down, solvents are flushed from the soil underneath the building and into the treatment zone of the AAB system. Monitoring of the site shows that complete biodegradation of the solvents is occurring within the treatment zone. Consequently, this ROD selects the ongoing AAB treatment as the final remedy to address the source materials at OT41/Bldg. 719.

Remedial Action Objectives (RAOs): RAOs were developed to address the human health risks associated with contaminants at all seven sites, and the adverse environmental condition associated with potential off-Base migration of Area 6 groundwater contamination at levels exceeding federal MCLs. Additionally, RAOs were developed to ensure that land use remains consistent with the scenarios used to assess risk at the sites. The RAOs for soil and groundwater contamination at the seven sites, and for the entire Area 6 plume, are discussed in Section 2.7 and are summarized as follows:

- Reduce concentrations of contaminants of concern (COCs) in the Columbia Aquifer to Federal MCLs. Quantitative groundwater RAOs are listed in Table 8, Section 2.7.
- Prevent exposure to groundwater from the Columbia Aquifer until cleanup levels are achieved.
- Maintain the asphalt cover at SS59 to prevent human exposure to residual pesticides in surface soil, and to reduce infiltration of surface water that may leach pesticides into groundwater, until concentrations of hazardous substances at the site are shown to be at levels allowing for unrestricted exposure and unlimited use.

Land Use Control (LUC) Objectives: The Air Force has identified the following LUC performance objectives:

- Prohibit the development and use of Sites WP21, WP31, ST34, OT41/Bldg 719, OT48, and SS59 for residential housing, elementary or secondary schools, day care centers, and playgrounds until concentrations of hazardous substances at the site are at levels allowing for unrestricted exposure and unlimited use.
- Prohibit the use of on-Base groundwater from the Columbia Aquifer (first shallow, unconfined aquifer) within the West Management Unit until cleanup levels are met and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use.
- Prohibit digging and other ground-disturbing activities at all of the sites that are inconsistent with the objectives listed above.
- Maintain the integrity of any current and future remedial or monitoring system at these sites.

Major Components of the Selected Remedy: The selected remedy documented in this ROD includes the following major components:

- Continued treatment of source materials at Site OT41/Bldg. 719 using the installed AAB recirculation system. An AAB groundwater recirculation treatment system was installed at OT41/Bldg. 719 under an interim ROD (see Sections 2.1.4, 2.3, and 2.8.1.9 for details). It is successfully treating the source area of chlorinated VOCs at the site via injection of an organic carbon material into the groundwater underneath Building 719. The injected carbon material enhances anaerobic conditions that stimulate naturally occurring bacteria to biodegrade the contaminants. As the water table fluctuates, contaminants are also flushed from the soil underneath the building and into the treatment zone. The remedy selected in this ROD includes the continued treatment of contamination at Site OT41/Bldg. 719 using the AAB recirculation system.
- Injection/diffusion AAB to treat groundwater contaminants at two target areas within the Area 6 plume, where the highest total chlorinated VOC concentrations are located. An organic carbon material will be periodically injected into the groundwater, via installed wells or a mobile probe, to enhance anaerobic conditions and stimulate naturally occurring bacteria to biodegrade the contaminants. Treating these areas of highest contaminant concentrations will reduce contaminant load on the downgradient portion of the Area 6 plume.
- Natural attenuation to address the portions of the Area 6 groundwater plume that are not treated via AAB.
- Periodic monitoring of groundwater to assess remedy performance.
- Maintenance of the asphalt cover system at SS59. An asphalt cover was installed at SS59 under an interim ROD (see Sections 2.1.4, 2.3, and 2.8.1.10 for details).

It prevents unacceptable human exposure to residual pesticide-contaminated soil, and reduces infiltration of rainwater that may leach pesticides into groundwater. The remedy selected in this ROD includes maintenance of the SS59 asphalt cover system to assure its integrity.

- No further action for the soil medium at Site OT28.
- Land use controls (LUCs) are a component of the selected remedy. They are discussed in more detail below.

The LUCs portion of the remedy for Area 6 includes the following provisions:

- Residential use, schools, on-site day-care centers and recreation areas are prohibited until concentration of hazardous substances at the sites are at levels allowing for unrestricted exposure and unlimited use.
- Prohibit the use of on-Base groundwater from the Columbia Aquifer (first shallow, unconfined aquifer) within the West Management Unit until cleanup levels are met and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use.
- Prohibit digging and other ground-disturbing activities at all of the sites that are inconsistent with the objectives listed above.
- Use of the Base General Plan as the implementation plan for LUCs. DAFB will update the Base General Plan to include the LUC requirements for these sites.
- Compliance with Air Force administrative procedures for review and prior approval by environmental personnel of proposed construction or subsurface soil disturbing activities (Base digging permit process).
- Visual site inspections and reporting on an annual basis to verify compliance with LUC requirements, and prompt notification to regulators of any LUC deficiencies.
- Compliance with the notification requirements of CERCLA Section 120(h) prior to any transfer or sale of property at the sites.
- Enforcement of well installation restrictions on-Base and at nearby off-Base properties per the Groundwater Management Zone (GMZ) established by the Delaware DNREC.
- Maintain the integrity of any current and future remedial or monitoring system at these sites.

The Air Force, represented by the 436th Airlift Wing Commander at DAFB, is responsible for implementing, monitoring, reporting on, and enforcing these LUCs with the exception of the GMZ, which is the responsibility of DNREC. All of the use and activity restrictions and controls set forth in this ROD shall remain in place until concentrations of hazardous substances at the sites are shown to be at levels allowing for unrestricted exposure and unlimited use. The Air Force shall not modify or terminate LUCs, implementation actions, or modify land use without prior approval by EPA and the State. The Air Force shall seek prior concurrence before any anticipated action that may disrupt the effectiveness of the LUCs or any action that may alter or negate the need

for LUCs. Section 2.8.1.11 provides a detailed description of each of the above listed LUCs.

1.4 STATUTORY DETERMINATION

The selected remedy is protective of human health and the environment, complies with Federal and State applicable or relevant and appropriate requirements (ARARs), and is cost-effective. The remedy for the Area 6 sites utilizes permanent solutions and alternative treatment technologies to the maximum extent possible. This remedy also satisfies the statutory preference for treatment as a principal element of the remedy. The remedy will prevent or control human exposure to contaminated media through implementation of LUCs. Because the remedy will result in hazardous substances remaining on-site above levels that allow for unrestricted exposure and unlimited use, a statutory review will be conducted in accordance with NCP §300.430(f)(4)(ii) within five years after initiation of the remedy to ensure that the remedy is protective of human health and the environment.

1.5 ROD DATA CERTIFICATION CHECKLIST

The following information appears in the Decision Summary section (Part II) of this ROD. Additional information regarding the Area 6 sites can be found in the DAFB Administrative Record.

1. COCs are summarized with their maximum detected concentrations and detection frequencies in Table 3.
2. Baseline human health risks due to the COCs are summarized in Table 5.
3. Results of the Basewide Ecological Risk Assessment (ERA) are discussed in Section 2.6.2.
4. The RAOs established for Area 6 and associated sites are discussed in Section 2.7.
5. Section 2.10 discusses how source materials constituting principal threats are addressed.
6. Current and reasonably anticipated future land and groundwater use are discussed in Section 2.5.
7. Potential land and groundwater uses that will be available as a result of the selected remedy are discussed in Section 2.11.4.
8. Section 2.11.3 and Table 14 summarize the estimated capital, annual operation and maintenance (O&M), and total present worth costs; discount rate; and the number of years over which the remedy costs are projected.
9. The key factors that led to the selection of the remedy are discussed in Section 2.9 and summarized in Section 2.11.

1.6 AUTHORIZING SIGNATURES AND SUPPORT AGENCY CONCURRENCE

This signature sheet documents the agreement between the United States Air Force and the United States Environmental Protection Agency on the Record of Decision for Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, and the Area 6 groundwater plume in the West Management Unit, Dover Air Force Base, Delaware.

Allan Ferdas — 1/26/06

ABRAHAM FERDAS
Director
Hazardous Site Cleanup Division
U.S. Environmental Protection Agency, Region 3

Date

Samuel D. Cox — 12 Jan '06

SAMUEL D. COX, Colonel, USAF
Commander, 436th Airlift Wing
Dover AFB, DE

Date

SUPPORT AGENCY CONCURRENCE

The Delaware Department of Natural Resources and Environmental Control has reviewed this Record of Decision for Area 6 and the materials on which it is based, and concurs with the selected remedy.

Kathleen Stiller Banning — January 17, 2006

KATHLEEN STILLER BANNING
Environmental Program Manager
Site Investigation and Restoration Branch
Delaware Department of Natural Resources and
Environmental Control

Date

PART II: DECISION SUMMARY

2.0 SITE NAMES, LOCATION, AND DESCRIPTION

Site Name: WP21, former wastewater lagoons and concrete waste basins
WP31, two former USTs
ST34, former fuel oil UST/equipment maintenance area
OT41/Bldg. 719, a portion of the former IWCD, expanded to include a former degreasing operation at Building 719
OT48, two oil/water separators
SS59, an open storage area
OT28, former wastewater treatment plant
Area 6, multi-source groundwater plume associated with the seven sites listed above

Location: West Management Unit (WMU), Dover Air Force Base, Delaware

National Superfund Electronic Database Identification Number: DE8570024010

Lead Agency for CERCLA Activities at DAFB: United States Air Force (USAF)

Lead Regulatory Agency: United States Environmental Protection Agency (USEPA) Region 3

Support Agency: Delaware Department of Natural Resources and Environmental Control (DNREC)

Funding Source: Air Force Environmental Restoration Account

Site Type: WP21 – Industrial Waste Pits
WP31 – Underground Storage Tanks
ST34 – Underground Storage Tank
OT41 – Industrial Waste Collection Drain
OT48 – Oil/water Separator
SS59 – Industrial Facility Surface Spill
OT28 – Wastewater Treatment Plant

Site Description: DAFB is located in Kent County, Delaware, about 3.5 miles southeast of the city of Dover (Figure 1, inset map) and is bounded to the southwest by the St. Jones River. DAFB encompasses approximately 4,000 acres of land, including annexes, easements, and leased property. The surrounding area is primarily cropland and wetlands. A large gravel quarry is located next to a portion of the Base's southwest boundary.

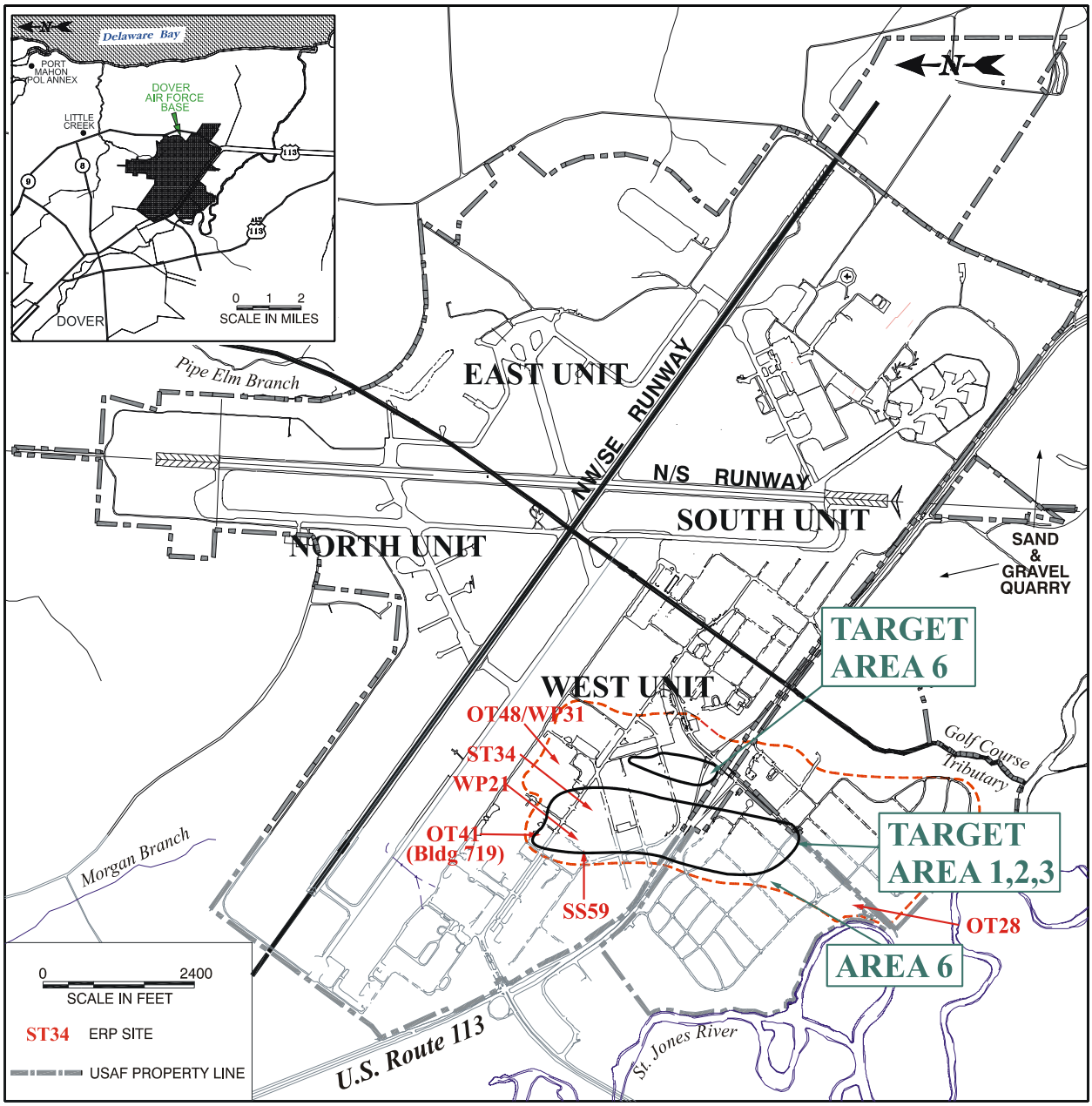


FIGURE 1. LOCATION OF AREA 6 AND ASSOCIATED SITES

DAFB began operations in December 1941. Since then, various military services have operated out of DAFB. The present host organization is the 436th Airlift Wing, a part of the USAF Air Mobility Command (AMC). Its mission is to provide global airlift capabilities, including transport of cargo, troops, equipment, and relief supplies. The Base also serves as the joint services port mortuary, designed to accept casualties in the event of war.

On March 13, 1989, DAFB was placed on the USEPA NPL for Superfund. In August 1989, the USAF entered into a Federal Facility Agreement (FFA) with USEPA Region 3 and the State of Delaware to facilitate environmental cleanup activities at DAFB. Subsequently, investigations were conducted under the Air Force ERP (formerly the Installation Restoration Program).

The sites addressed in this ROD—WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28—are located in the industrialized portion of the Base—in the WMU (Figure 1). This unit is one of four management units (North, South, East, and West) into which the Base has been divided for the purpose of conducting the Basewide RI (U.S. Army Corps of Engineers [USACE], 1994 and 1997b). The WMU contains 39 of the 59 ERP sites identified at DAFB, including the seven sites addressed in this ROD. Section 2.3 summarizes how the other 32 WMU sites are being addressed.

The WMU of DAFB is heavily industrialized northeast of U.S. Route 113, and six of the seven ERP sites included in this ROD are located in that area (Figure 1). Base housing and a portion of the golf course lie southwest of U.S. Route 113. OT28 is located at the far west edge of the Base housing area. These sites and Area 6 are defined as follows:

- WP21. A pair of former industrial waste lagoons that have undergone Resource Conservation and Recovery Act (RCRA) closure. The site was expanded to include two adjacent former concrete waste basins. The site is currently maintained as an open grassy field.
- WP31. Two former USTs located between two aircraft maintenance hangars. One held waste oil and the other fuel oil. There is mixed fuel and solvent contamination at this site.
- ST34. A former fuel oil UST in an equipment maintenance area. There is mixed fuel and solvent contamination at this site.
- OT41/Bldg. 719. A portion of the IWCD that was expanded to include Building 719 when studies revealed a solvent release below the building's former engine cleaning rooms.
- OT48. Two existing oil/water separators at an avionics maintenance facility.
- SS59. An open storage area where soil contaminated with pesticides was found.
- OT28. A former wastewater treatment plant. The plant was dismantled in 1975 and the area is occasionally used for open storage of non-hazardous materials and equipment.

- Area 6. Area 6 is the multi-source groundwater plume to which each of the seven sites have contributed contamination.

Within the Area 6 plume, two "target areas" have been identified for purposes of evaluating remedial alternatives. The target areas are locations where contaminant concentrations are the highest (>1,000 µg/L total chlorinated solvents) relative to the rest of the Area 6 plume. For consistency with the RI and FS reports for the WMU (USACE, 1997b and 2005), these two target areas are called "Target Area 1,2,3" and "Target Area 6" (Figures 1 and 2).

2.1 SITE HISTORY AND ENFORCEMENT ACTIVITIES

2.1.1 WP21

WP21 was originally a pair of unlined industrial waste lagoons built in 1963 to receive wastes from the engine overhaul shop (Bldg. 719; Figure 1). At that time, the system included a 12,000-gallon-capacity primary basin, a 170,000-gallon-capacity secondary impoundment, and an underground pipe through which waste flowed after passing through an oil/water separator. In 1968, the system was expanded to accept wastewater from other Base facilities via the industrial waste collection drain (Site OT41). The wastewater was processed first through two concrete basins and two oil/water separators (Site OT46). From the lagoons, treated wastewater was sent to several locations during the two decades they were in operation: from 1963 to 1969 wastewater was discharged to the north drainage ditch (Site SD12); from 1969 to 1975 to the DAFB Wastewater Treatment Plant (Site OT28); and from 1975 to 1986 to the Kent County Wastewater Treatment Plant. In 1986, the two unlined industrial waste lagoons were taken out of service and remediated. The two concrete basins and two oil/water separators continued to process industrial wastewater until 1998, when they were taken out of service and remediated. These actions are discussed in the following paragraphs.

Two soil cleanup actions have been conducted at Site WP21, and groundwater treatability studies have been conducted at the site. In 1986, the two unlined industrial waste lagoons underwent RCRA closure. The lagoons (sludge and underlying soil) were excavated, filled with clean soil, and capped, and DAFB applied for a RCRA post-closure permit. In November 1987, DNREC issued a Secretary's Order (State enforcement action) for failure to submit a complete permit application. The Secretary's Order was subsequently modified in May 1989, and required DAFB to collect and submit data for purposes of determining groundwater cleanup requirements. Periodic groundwater monitoring was initiated under the modified Secretary's Order during the early 1990s, and a treatability study was conducted to evaluate an Aquifer Air Sparging/Soil Vapor Extraction (AAS/SVE) technology to treat chlorinated solvents in groundwater (EA, 1993 and 1994). The Secretary's Order was superseded in 1995 when DNREC issued a Post-Closure Permit for Site WP21. The original permit required operation of the AAS/SVE system and submittal of periodic groundwater monitoring reports. In 1996, the AAS/SVE technology was deemed a failure, and the system operation was terminated. From 1996 through 1998, a natural attenuation study was conducted in the Area 6 plume

as described in Section 2.1.8. As a result of that study, the WP21 Post-Closure Permit was modified in 1998 to include natural attenuation as an interim remedy for groundwater contamination at the site. Periodic groundwater monitoring is currently ongoing under the Post-Closure Permit. Upon implementation of the AAB remedy at WP21, DNREC and DAFB have agreed to terminate the RCRA Post-Closure permit for WP21, and conduct future actions under this ROD and CERCLA requirements.

The second soil cleanup action at WP21 was initiated after a 1997 investigation (Hazardous Waste Remedial Actions Program (HAZWRAP), 1997a). This investigation revealed the presence of soil contamination near the concrete waste basins that was a probable continuing source of contamination to groundwater. Therefore, in 1998, a ROD was signed to address the soil contamination associated with the concrete basins (DAFB, 1998). The two concrete waste basins, oil/water separators (ERP Site OT46), and 2,755 tons of contaminated soil were removed and sent off-site for treatment and disposal (AIMTech, 2000). The RAOs for this action, reduction of concentrations of soil contaminants to below their USEPA Soil Screening Levels for Transfers from Soil to Groundwater (SSL_{gw}), were met. Additionally, the RCRA cap that had been installed in 1986 was removed from the area of the former unlined lagoons because soil sampling showed no residual contamination underneath the cap. The entire area was backfilled with clean fill and sodded, and the site is currently maintained as an open grassy field.

2.1.2 WP31

WP31 is the location of two former USTs between Buildings 780 and 781, aircraft maintenance hangars (Figure 2). One was a 500-gallon-capacity waste oil tank and the other held 1,000 gallons of fuel oil. Both USTs were removed in 1989 and the area backfilled with soil. As these actions occurred prior to the adoption of the DNREC UST regulations, no closure report was prepared and it is unknown whether there were signs of leakage. Soil sampled during the subsequent site investigation in 1991 (HAZWRAP, 1991) revealed residual contaminants suggesting that one or both of the USTs had leaked. Mixed solvent and fuel-related contaminants were found in site groundwater during the Basewide RI in 1993 (USACE, 1997b). Other than the UST removals in 1989, no cleanup actions have taken place at this site. There have been no CERCLA or other enforcement activities at this site.

2.1.3 ST34

ST34 is the location of a former fuel oil UST between Buildings 608 and 609 (Figure 2). Equipment maintenance activities occur at these buildings. The UST (capacity and construction unknown) reportedly leaked for an unknown period of time. It was removed in 1987 at which time free product was observed in the excavation and the visibly contaminated soil was reportedly removed. No closure report or analytical data are available from this activity since it occurred before the adoption of DNREC's UST regulations. Several phases of environmental investigation have occurred at ST34.

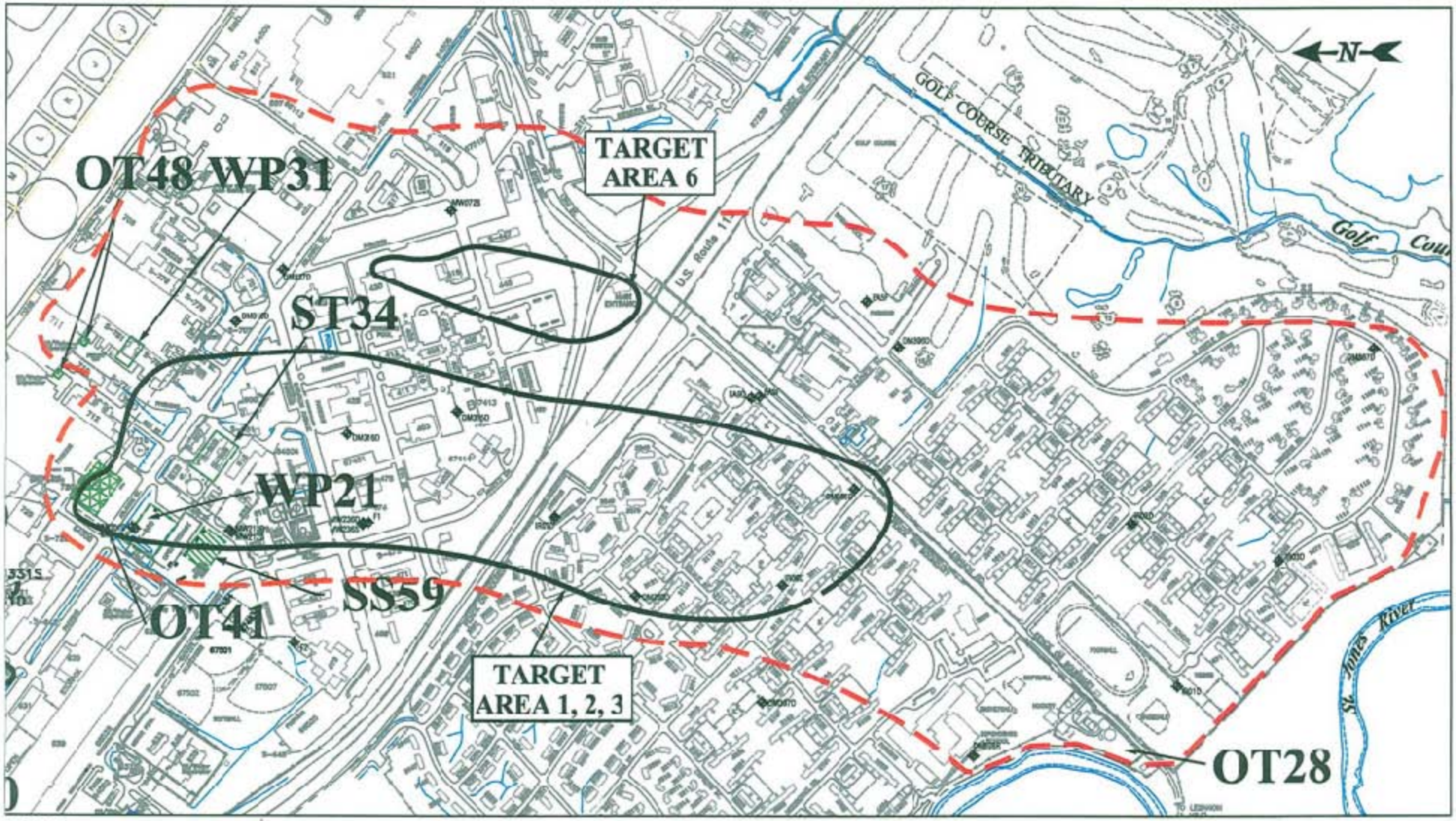


FIGURE 2
AREA 6 SITE MAP

URS

Soil and groundwater were sampled during site investigations in 1988 and 1989 (SAIC, 1989 and HAZWRAP, 1990), and during the Basewide RI (USACE, 1997b). Mixed-waste contaminants including solvents and fuel were found in site groundwater, indicating that releases occurred from the UST or other maintenance activities at this site. Other than the UST removal in 1987, no cleanup actions have taken place at this site. There have been no CERCLA or other enforcement activities at this site.

2.1.4 OT41/Bldg. 719

Site OT41 is the IWCD that collects industrial wastewater from several maintenance facilities and transports it to a county lift station on the west side of the Base. Wastewater ultimately discharges to the Kent County Wastewater Treatment Plant. There are two locations along the IWCD that require cleanup action. The first location, at Building 719, is addressed in this ROD under the designation OT41/Bldg. 719. The second IWCD location that requires cleanup action is at the former Base motor pool, and is designated as OT41/Motor Pool. The OT41/Motor Pool location is being addressed in the ROD for the Area 5 groundwater plume as discussed in Section 2.3.

OT41/Bldg. 719 was originally a portion of the IWCD next to Building 719, a jet engine maintenance facility (Figure 2). The solvent trichloroethene (TCE) was used to degrease engine parts in this facility during the 1960s. Two former USTs located between the IWCD and Bldg. 719 may also have been sources of contamination. The solvent degreasing process at Building 719 was terminated in the early 1970s. The USTs were removed in 1992. No information regarding subsurface conditions is available from that activity. The IWCD was first investigated during a 1991 site investigation when a soil gas survey was conducted (HAZWRAP, 1991). Soil and groundwater were sampled at the site during the Basewide RI in 1993 (USACE, 1997b). Site OT41 was expanded to include Building 719 itself when investigation revealed a significant chlorinated solvent source below the engine cleaning rooms.

Two interim cleanup actions have been conducted at OT41/Bldg. 719. Under a 1995 interim ROD (DAFB, 1995c), a soil co-metabolic bio-venting system was installed in the area of the former USTs. The interim RAO for soil was to reduce the concentration of each ethyl-based chlorinated VOC by 90 percent from its maximum detected concentration. The co-metabolic bio-venting interim remedy operated from 1997-1998, during which time the interim soil cleanup goal was met (USEPA, 2000). Under a second 1995 interim ROD (DAFB, 1995b), an AAB recirculation system was developed, pilot tested, and a full-scale system installed at OT41/Bldg. 719. The purpose of the AAB system is to treat the major chlorinated solvent source underneath Building 719. Operation of the AAB system began in 2002 and is ongoing. Complete degradation of chlorinated solvents is being observed. Therefore, the AAB system at Building 719 is being included as a component of the selected remedy in this ROD. Section 2.8.1.9 describes the AAB recirculation system in more detail. There have been no CERCLA or other enforcement activities at this site.

2.1.5 OT48

OT48 is the location of two below-ground oil/water separators at the south and west corners of Building 711, an avionics maintenance facility (Figure 2). The concrete separators were installed in 1969 and each is 7 x 9 x 10 feet (ft) deep with an associated 400-gallon-capacity holding tank for accumulated waste oil. The separated water is discharged to the sanitary sewer. Two phases of investigation have occurred at OT48. Soil was sampled during a site investigation in 1991 (HAZWRAP, 1991). Both soil and groundwater were sampled in 1993 during the Basewide RI (USACE, 1997b). Solvent and fuel-related contaminants were found in site groundwater. To date, no cleanup actions have taken place at this site. There have been no CERCLA or other enforcement activities at this site.

2.1.6 SS59

SS59 is an open storage area adjacent to Site WP21. It has historically been used for the temporary storage of various materials, some of which may have been hazardous (Figure 2). It has also been referred to as the Paint Washout Area and Lindane Source Area. SS59 is located downgradient of Sites OT41/Bldg 719 and WP21. As such, chlorinated solvent contamination in groundwater from these other sites flows underneath Site SS59. However, SS59 was identified as a separate site when Lindane (a pesticide) was found in groundwater at the site during the 1993 Basewide RI (USACE, 1997b). Lindane is not found at the upgradient sites. Subsequent to the RI, a soil investigation revealed the presence of several pesticides in shallow soil at SS59 at levels indicative of spills rather than normal application (HAZWRAP 1996 and 1997c). An interim ROD for the Lindane Source Area was signed in 1995. An Engineering Evaluation and Cost Analysis was prepared (HAZWRAP, 1997b), and a removal/capping action for pesticide-contaminated soil was conducted during 1998-1999. Approximately 147 tons of surface soil were excavated and incinerated at an off-Base location. Residual contaminants remained in surface soils at levels exceeding industrial soil screening criteria for pesticides. Therefore, the area was covered with an asphalt capping system to prevent human exposure and reduce infiltration of rainwater, thus protecting groundwater from pesticides that may leach from the soil (AIMTech, 2000). The soil action at SS59 is discussed in more detail in Section 2.8.1.10. While Site SS59 is within the portion of Area 6 that is undergoing groundwater monitoring, no specific groundwater remedies have been conducted at the site. There have been no CERCLA or other enforcement activities at this site.

2.1.7 OT28

OT28 is the former wastewater treatment plant located at the western edge of the Base near Base housing and next to the St. Jones River (Figure 2). The plant originally processed sanitary effluent; however beginning in 1969 it received treated industrial wastewater until its closure in 1975. The plant has been dismantled, and the area is now fenced. It is occasionally used for storage of non-hazardous equipment and materials. Two investigations have occurred at OT28. Surface water from the St. Jones River was

sampled during the site investigation in 1991 (HAZWRAP, 1991). Sediment, soil, and groundwater were sampled during the Basewide RI in 1993-1994 (USACE, 1997b). To date, no cleanup actions have taken place at this site. There have been no CERCLA or other enforcement activities at this site.

2.1.8 Area 6

Area 6 is the largest multi-source groundwater contaminant plume at DAFB (Figure 2). The sites described above contribute primarily chlorinated solvents although fuels and Lindane (a pesticide) are also minor components of the Area 6 plume. The sources are generally located in the central part of the WMU at industrial sites and a plume of commingling contaminants extends downgradient across U.S. Route 113 and into the deep portion of the Columbia Aquifer underneath Base housing. Under a 1995 interim ROD (DAFB, 1995a), a three-year study was conducted by the Remediation Technologies Development Forum (RTDF) demonstrating the effectiveness of natural attenuation in remediating the contaminants in the Area 6 plume. The monitoring program for the RTDF project transitioned into the long-term monitoring of a portion of Area 6 and merged with the RCRA post-closure monitoring for WP21. This effort is ongoing. Two "target areas" within the Area 6 plume are defined in the WMU FS to assist with remedial alternative layouts (USACE, 2005). The larger target area is called "Target Area 1,2,3" and the smaller is called "Target Area 6" (Figure 2). Target areas define regions of highest contaminant concentrations in groundwater. The boundaries of the Target Areas were defined in the WMU FS as areas where total chlorinated solvent concentrations exceeded 1000 µg/L, based on data available at that time. The Target Areas were used as a tool during the FS to help in determining the best application of source area treatment alternatives.

2.2 COMMUNITY PARTICIPATION

DAFB actively encourages public participation at all phases of environmental restoration work, and operates under a Community Relations Plan that is periodically updated. In accordance with NCP §300.430(f)(3) and Delaware RCRA requirements, the Proposed Plan for Area 6 at DAFB and supporting documentation were made available to the public in July 2005. They can be found in the Administrative Record file and the Information Repository maintained at the 436th Civil Engineer Squadron DAFB and the Dover Public Library. The notice of availability for the proposed plan was published in the Delaware State News and the News Journal on July 3, 2005. A public comment period was held from July 10 to August 24, 2005. A public meeting was held on July 19, 2005, at the DNREC auditorium, 89 Kings Highway, Dover, Delaware. No oral or written comments from the public were received during the public comment period or at the public meeting. This is documented in Part III, the Responsiveness Summary in this ROD.

2.3 ROLE AND SCOPE OF RESPONSE ACTIONS

As discussed in Section 2.0, for purposes of conducting the RI/FS, DAFB was divided into four management units, and the sites addressed in this ROD are those associated with the Area 6 groundwater plume in the WMU. There are a total of 39 ERP sites in the WMU, including the seven sites being addressed in this ROD. DAFB's general cleanup strategy is to group sites within their associated groundwater plumes, and address cleanup requirements by plume. Sites not requiring groundwater remediation, and sites being addressed under authorities other than CERCLA, are similarly grouped and addressed. Thus, the Area 6 groundwater plume and its seven associated sites are being addressed as one operable unit in this ROD. Similarly, the 32 other ERP sites in the WMU are being addressed as follows:

- Area 5 ROD: This ROD will include Sites OT51, OT50, SS20, OT44, and OT41/Motor Pool which contribute to the Area 5 groundwater plume.
- LF25 and SS08 ROD: These are discreet sites, each with their own distinct groundwater plume. They will be addressed in one ROD because the types of contaminants and selected remedies are the same for both sites.
- ROD for LUCs at Multiple Sites: FT02, LF24, LF26, WP33, WP38, OT42, OT43, OT45, OT46, OT47, OT49, and OT57 do not require further soil or groundwater remediation. They are all being addressed under a single ROD for implementation of LUCs.
- No further action site: A no further action ROD for Site OT40 was signed in 1994.
- Sites SS27, ST05, ST37, WP30, SS09, SS10, ST11, OT52, OT54, SS36, ST35, and ST04 are petroleum exclusion sites. These sites are being addressed under the State of Delaware's Tank Management Program per the Delaware Regulations Governing Underground Storage Tank Systems. Sites SS27, ST05, and ST37 have fuel recovery remedies in place and operating. The State of Delaware has issued no further action letters for Sites WP30, SS09, SS10, ST11, OT52, OT54, SS36, ST35, and ST04.

For the seven sites addressed in this ROD (WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28), no action is required for surface water or sediment because unacceptable risks were not found in these media. For soil and groundwater at the Area 6 sites, the following is a summary of the cleanup strategy, which is an on-going multi-step process. The strategy is organized into three parts:

(1) DAFB's first considerations were to address source materials constituting principal threats, soil contamination that could pose a continuing threat to groundwater, and soil contamination that could pose risks to on-Base workers at the seven sites. All required soil cleanup actions for the seven sites have been completed using industrial cleanup standards.

(2) The second part of the Area 6 cleanup strategy was to conduct interim groundwater remedies. The purpose of these interim remedies was to collect data for use in evaluating alternatives for the entire Area 6 groundwater plume, and to begin remediating areas of the highest contaminant concentrations.

(3) The final stage of the Area 6 cleanup strategy, which is addressed in this ROD, is to implement the final groundwater remedy, and to implement the controls necessary to ensure that land use restrictions and groundwater use prohibitions are maintained. The selected remedy discussed in this ROD addresses all remaining response actions required for all media at the seven sites and the Area 6 groundwater plume.

Past and ongoing actions associated with parts 1 and 2 of the strategy described above, and the planned response actions associated with part 3 of the strategy, are summarized below. Past actions include response actions taken prior to the initiation of the Air Force ERP, as well as those taken under the Air Force ERP. Actions taken under the Air Force ERP have been assigned a USEPA operable unit number as identified in the discussions below. The planned response actions discussed below, highlighted in bold, are all components of the selected remedy documented in this ROD.

(1) Past Soil Actions:

- In 1986, the unlined waste lagoons at Site WP21 underwent RCRA closure; sludge and soil were excavated and a clay capping system was installed.
- In 1987, the UST at Site ST34 was removed.
- In 1989, the two USTs at Site WP31 were removed.
- In 1992, the USTs at Site OT41/Bldg. 719 were removed and the IWCD was removed from service.
- In 1996 (under a 1995 interim ROD; USEPA Operable Unit #12), a soil co-metabolic bio-venting system was installed at OT41/Bldg. 719 in the area of the former USTs. The system operated from 1998 to 1999. The interim soil RAO was to reduce the concentrations of each chlorinated VOC by 90 percent from its maximum detected concentration. The RAO was met, however, soil contamination possibly remains underneath Building 719 where the co-metabolic bio-venting system did not reach. See first bullet under Ongoing Interim Groundwater Actions section below.
- In 1998 (under a 1998 interim ROD; USEPA Operable Unit #14), the concrete industrial waste basins at WP21 were removed; contaminated soil was excavated and treated off-site. The RCRA capping system was also removed with State concurrence. USEPA Region 3 Risk-Based Concentrations (RBCs) for commercial/industrial soil ingestion were used as the soil cleanup standard.
- In 1998-1999 (under a 1995 interim ROD; USEPA Operable Unit #5), pesticide-contaminated soil at Site SS59 was excavated and sent off-site for incineration. USEPA Region 3 commercial/industrial RBCs were used as cleanup guidelines.

An asphalt capping system was installed to prevent unacceptable human exposure to residual pesticides and reduce rainwater infiltration, thus protecting groundwater from residual pesticides that might otherwise leach from the soil.

(2) Ongoing Interim Groundwater Actions

- Site OT41/Bldg. 719 is the only remaining site within Area 6 where principal threat wastes may still be present (i.e., material is present in soil that may act as a reservoir for migration of contaminants to groundwater). These wastes may be present underneath Building 719 where a suspected drain pipe leak may have released TCE into the ground. In 2001 (under a 1995 interim ROD; USEPA Operable Unit #11), an AAB recirculation system was installed at Building 719. The system has been operating since 2002. The purpose is to treat the source area of chlorinated solvent contamination underneath Building 719. While this is primarily a groundwater remedy, it is also treating the otherwise inaccessible residual soil contamination underneath the building as groundwater table fluctuations bring the water level to within inches of the foundation of the building, thus flushing the soil contaminants into the groundwater treatment zone. This remedy is ongoing, and is a component of the selected remedy presented in this ROD.
- Starting in 1996 (under a 1995 interim ROD; USEPA Operable Unit #10), a monitored natural attenuation remedy was implemented for a portion of the Area 6 groundwater plume known as Target Area 1. Periodic groundwater monitoring is ongoing under this remedy. Natural attenuation is a component of the selected remedy presented in this ROD.

(3) Planned Response Actions (Actions Addressed in this ROD)

- **The selected remedy presented in this ROD is the final response action for all seven sites and the Area 6 groundwater plume as a whole. This ROD addresses the one remaining area of possible soil contamination and the groundwater contaminant source area at OT41/Bldg. 719 through continued operation of the AAB recirculation system. It addresses groundwater contamination at the other seven sites and the remainder of the Area 6 plume through a combination of 1) injection/diffusion AAB in target areas with the highest contaminant concentrations, and 2) natural attenuation in areas of lower contaminant concentrations (primarily downgradient areas). LUCs will be implemented to: 1) Prohibit the development and use of WP21, WP31, OT41/Bldg 719, OT48, and SS59 for residential housing, elementary or secondary schools, day care centers, and playgrounds until concentration of hazardous substances at the site are at levels allowing for unrestricted exposure and unlimited use. 2) Prohibit the use of on-Base groundwater from the Columbia Aquifer (first shallow, unconfined aquifer) within the West Management Unit until cleanup levels are met and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use. 3) Prohibit digging and other ground-**

disturbing activities at all of the sites that are inconsistent with the objectives listed above. 4) Maintain the integrity of any current and future remedial or monitoring system at these sites. These components of the selected remedy are further described in Sections 2.8.1.9, 2.8.1.10, and 2.8.1.11 of this ROD. The following is a breakdown of these components of the selected remedy as they apply to each site and the Area 6 plume:

- **WP21: Injection/diffusion AAB and natural attenuation to address groundwater contamination, and periodic monitoring. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **WP31: Natural attenuation to address groundwater contamination, and periodic monitoring. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **ST34: Injection/diffusion AAB and natural attenuation to address groundwater contamination, and periodic monitoring. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **OT41/Bldg. 719: Continuation of AAB recirculation system operations and periodic monitoring. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **OT48: Natural attenuation to address groundwater contamination and periodic monitoring. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **SS59: Injection/diffusion AAB and natural attenuation to address groundwater contamination, and periodic monitoring. Maintenance of the asphalt cover over the site. LUCs to control exposure to soil, maintain the monitoring system, and prevent exposure to groundwater.**
- **OT28: Natural attenuation to address groundwater contamination and periodic monitoring. LUCs to prevent exposure to groundwater and maintain the monitoring system. No further action is required for soil at OT28.**
- **Area 6 Groundwater Plume: Injection/diffusion AAB and natural attenuation to address groundwater contamination, and periodic monitoring. LUCs to prevent exposure to groundwater and maintain the monitoring system.**

2.4 SITE CHARACTERISTICS

2.4.1 Conceptual Site Models

WP21. As a result of processing industrial wastes, the unlined lagoons at this site released contaminants to the subsurface that migrated through the soil column and into the shallow water table (the Columbia Aquifer). Removal of the lagoons and underlying soil mitigated the original WP21 source area, however contaminants in groundwater were transported downgradient and deeper within the aquifer as groundwater flowed southward towards the St. Jones River, the local discharge point. This site also includes the adjoining concrete basins, one of which leaked and released contaminants. The concrete basins and contaminated soil were removed but, as with the former lagoons, groundwater contamination was transported from the basin area downgradient and deeper within the aquifer. This site is located in the upgradient portion of the Area 6 groundwater plume (Figure 2).

WP31. One or both of two former USTs at this site had released contamination to the subsurface. These contaminants migrated through the soil column and into the shallow water table (the Columbia Aquifer). Removal of the UST and surrounding soil mitigated the original source although sampling indicated residual contaminants are present in soil. These contaminants have also affected groundwater along the eastern edge of the Area 6 plume.

ST34. The former UST was known to have released contaminants to the subsurface and the maintenance activities at the adjacent shops were also possible sources of contaminants found at this site. Removal of the UST and surrounding soil mitigated the original source and sampling indicated no residual contaminants in soil. However, prior to the removal, contaminants migrated through the soil column and into the Columbia Aquifer near the core of the Area 6 groundwater plume.

OT41/Bldg. 719. The jet engine cleaning rooms were a major release point of contaminants into the subsurface soil below Building 719. Although two former USTs located adjacent to these rooms may also have released contaminants, they are overwhelmed by the cleaning rooms' source. This is the only site within Area 6 at which the subsurface soil contamination may be considered a principal threat waste. Contaminants from the soil have migrated downward into the shallow portion of the Columbia Aquifer at the upgradient edge of the Area 6 plume. They are transported with the flow of groundwater downgradient to the south. Since 2002, the source area beneath Building 719 has been undergoing treatment using an AAB recirculation cell, which is effectively containing the source contamination and reducing source concentrations. As the water table rises and falls, contaminants are desorbed from the soil into groundwater where they are then captured in the treatment system. This soil is inaccessible by standard remediation methods due to its location underneath an active aircraft maintenance facility.

OT48. Two oil/water separators at Building 711, an avionics maintenance facility, appear to have released contaminants into the surrounding soil. There is some indication that this may have happened during servicing of the separators since contaminant levels were higher in the soil closer to the ground surface. Over time, contaminants migrated through the soil column and into the shallow water table near the upgradient edge of the Area 6 plume.

SS59. Sampling indicates that pesticide spills occurred at this site, contaminating the shallow soils, primarily in localized 'hot spots.' One pesticide, Lindane, appears to have migrated through the soil column and into the shallow groundwater where it formed a narrow plume. A soil removal action has, to a large degree, mitigated the hot spots and an asphalt cover system reduces infiltration in the area that contains residual pesticides thus protecting groundwater. This cover also eliminates surface runoff from the affected soil.

OT28. The operation of the former wastewater treatment plant appears to have had little lasting effect on soil quality at the site. At some time in the past, however, some contaminants were likely released into the subsurface and migrated into the shallow water table aquifer near the toe of the Area 6 plume. Since this site is adjacent to the St. Jones River, it is likely that some discharge of contaminants to the river has occurred but sampling indicated that this is minimal.

Area 6. Each of the sites discussed above contribute contaminants to a groundwater plume called Area 6. OT41/Bldg. 719 is the single largest contributor. Subsurface soil contamination at the sites appears to exist at only residual levels except at OT41/Bldg. 719. Exposure to residual soil contamination is a possible exposure route for Base maintenance or utility workers at Area 6 sites.

In groundwater, the contaminants from each of the sites have commingled, forming a large plume of primarily chlorinated solvents. Benzene (a component of fuel) and Lindane (a pesticide) are minor components. These contaminants are found in the shallow portion of the aquifer near the industrial source areas and they migrate deeper within the aquifer as groundwater flows southward towards the St. Jones River. Groundwater from the Columbia Aquifer is not used for any purpose on Base at this time, thus there are no current exposures to this medium. In addition, modeling performed in the WMU FS has demonstrated that groundwater discharging to the St. Jones River (using worst-case assumptions) will not result in exceedances of State surface water standards during the time needed for remedy implementation. Thus, surface water is not a significant exposure route.

Vapor intrusion was generally not recognized as a human health exposure pathway that could be reliably quantified during the time (mid 1990s) that the RI risk assessments were conducted for DAFB. Thus, this pathway was not evaluated during the RI/FS process for the Area 6 sites. The assessment of risks from this potential pathway at DAFB occurred later. Risks were assessed in 2003 for the Base residential area during a public health assessment conducted by the Agency for Toxic Substances and Disease Registry

(ATSDR). The report concluded that there are no unacceptable risks from vapor intrusion in the Base housing buildings located within the flow path of the Area 6 solvent plume (ATSDR, 2003). The Air Force will re-evaluate the vapor intrusion pathway during the groundwater remedial action phase of the cleanup program for the Area 6 sites. This is discussed in more detail in Section 2.6.2.

2.4.2 Topographical and Hydrogeological Information

The surface topography of DAFB is relatively flat, with elevations ranging from 10 to 30 ft above mean sea level (msl). Areas of lower elevation (10 ft above msl or less) are located adjacent to the St. Jones River and Pipe Elm Branch (a tributary to the Little River). Elevations of 30 or more feet above msl occur in the housing area, which is located south of U.S. Route 113, in the western portion of the Base. Surface water runoff is handled by an extensive storm drainage network of open ditches and pipe culverts. The storm drainage network discharges primarily to the St. Jones River, the Pipe Elm Branch, and the Morgan Branch. Surface water in the northeast portion of the WMU is directed to the north drainage ditch (ERP Site SD12) and then to Pipe Elm Branch. Drainage for the remaining portions of the WMU is to the St. Jones River.

There are four groundwater aquifers underlying DAFB. They are, in descending order: the Columbia, the Frederica, the Cheswold, and the Piney Point. The water table aquifer at DAFB is the Columbia Aquifer. The water table is usually encountered at 10 to 15 ft below ground surface (bgs), but varies according to surface topography from 30 ft bgs to within a few feet of the ground surface. The Pleistocene sediments occupied by the Columbia Aquifer underlying DAFB consist of fine- to coarse-grained sand with gravelly sand, gravel, silt, and clay lenses common throughout. The upper portion of the Columbia Formation is finer grained and contains more silt and clay lenses than the deeper portions. The saturated thickness of the Columbia Aquifer ranges from 15 to 20 ft in the northern portion of the Base to 70 ft in the southeastern portion. The deeper portion of the Columbia Formation is typically fine- to coarse-grained sand with occasional lenses of fine to medium sand and discontinuous gravel lenses interpreted as channel lag deposits. The overall trend from coarser to finer material represents a change in depositional environment from higher to lower energy.

Underlying the Columbia Aquifer is a dense Miocene clay layer known as the Calvert Formation. It is approximately 20 ft thick. The contact between the Columbia and Calvert Formations forms a hummocky erosional surface, characterized by low mounds and ridges where the two formations meet. The Upper Confining Unit of the Calvert Formation generally consists of gray to dark gray, firm, dense clay, with thin laminations of silt and fine sand. It separates the Columbia Aquifer from the Frederica Aquifer, acting as a barrier to prevent the vertical migration of contaminants from the Columbia Aquifer to the Frederica Aquifer. In one localized area near the center of the Base, the confining unit appears to be thin or missing. The Frederica Aquifer is the upper sand unit of the Calvert Formation and underlies the upper clay and silt unit. The potentiometric surface of the Frederica Aquifer is generally 4 to 6 ft lower than the groundwater levels of the Columbia Aquifer except near groundwater discharge points such as the St. Jones

River where the levels are reversed. Below the Frederica Aquifer, the next two deeper aquifers are the Cheswold and Piney Point.

2.4.3 Ecology

DAFB is located on a broad, low coastal plain in the Atlantic Coastal Plain Physiographic Province know as the Delmarva Peninsula. This area is characterized by low desiccated (dry) hills and sandy plains and includes mature streams and wetland areas. Ecological habitat at DAFB comprises open grassy fields and areas adjacent to three main surface drainages: Pipe Elm Branch, St. Jones River, and Morgan Branch. These areas, where not covered by parking lots, buildings, or regularly mown grass, consist of low seral (dry, withered) vegetation, non-tidal emergent wetlands, mesic (moderate moisture) and wet hardwood forests, tidal swamp forests, and freshwater and brackish marshes. The best quality habitats (and the least disturbed) are found along the Pipe Elm Branch drainage in the East Management Unit. There is very little viable ecological habitat within the industrialized portion of the WMU.

2.4.4 Archaeological or Historical Significance

There are no areas of archaeological or historical significance at any of the Area 6 sites.

2.4.5 Sampling Strategy

Several environmental investigations were conducted prior to the Basewide RI (see Attachment 1 for reference list). However, the Basewide RI is the most recent and comprehensive evaluation of the entire WMU. These investigations and the RI were documented in the following reports:

- *USAF Installation Restoration Program – Dover AFB, Delaware, Phase II – Stage I Confirmation/Quantification* (Science Applications International Corporation [SAIC], 1986). Groundwater, surface water, and sediment sampling at WP21.
- *Installation Restoration Program – Stage 2 Report, Dover Air Force Base, Delaware* (SAIC, 1989). Soil gas survey and soil and groundwater sampling at ST34.
- *Installation Restoration Program, Draft Technical Memorandum: Sampling and Data Results, Sites T-1, SP-9, D-4, and DD-1, Dover Air Force Base, Delaware* (HAZWRAP, 1990). Soil gas surveys, subsurface soil and groundwater sampling at WP21 (formerly known as Site T-1).
- *Site Investigation Reports: WP31, OT41, OT48, OT28* (HAZWRAP, 1991). Surface and subsurface soil sampling at WP31; soil gas survey at OT41; surface and subsurface soil sampling at OT48; surface water sampling at OT28.
- *Ecological Risk Assessment, Phase I: Site Characterization, Dover AFB, Dover, Delaware* (HAZWRAP, 1993). Surface water and sediment sampling at OT28.

- *Basewide Remedial Investigation, Dover Air Force Base, Delaware [Area 6 Volumes I – IV and West Management Unit Volumes I – IV]* (USACE, 1994 and 1997b). Groundwater sampling at WP21; subsurface soil and groundwater sampling at ST34; surface and subsurface soil and groundwater sampling at WP31, OT41/Bldg. 719, OT48, SS59, OT28, and Area 6.

Other investigations and studies conducted concurrently with the RI or afterward include the following:

WP21.

- *Technical Report, Dover Air Force Base, Site WP21, Results of Aquifer Air Sparging/Soil Vapor Extraction, Treatability Study*, EA Engineering Science and Technology, Inc. (December 1993).
- *Draft Feasibility Study Report for WP21*, EA Engineering Science and Technology, Inc. (March 1994).
- *Summary Report, WP21 Soil Sampling, Dover Air Force Base, Delaware* (HAZWRAP, 1997a).
- *Closure Report for the Industrial Waste System Open Oil/Water Separator Basins, Dover Air Force Base* (HAZWRAP, 1999).

Soon after the RI sampling, DAFB had EA Engineering, Science, and Technology, Inc. prepare an FS and conduct a treatability study for AAS/SVE at WP21 and the adjoining Open Storage Area (first two bullets). Based on resulting monitoring data, DAFB, State, and federal regulators concluded that AAS/SVE was not a suitable remedy because the addition of oxygen to the aquifer disrupted the natural anaerobic degradation of chlorinated solvents. The AAS/SVE pilot was terminated in March 1996.

Additional soil samples were collected at WP21 in 1997 to assess conditions under and around the former lagoons (third bullet). The analytical data indicated that the soil beneath the former lagoon and near a lift station and connecting drain line were virtually free of VOCs. Samples collected at the adjoining concrete waste basins indicated a solvent release, and 1,1,1-trichloroethane (1,1,1-TCA) was the dominant constituent. The removal of the basins, contaminated soil, and the WP21 liner and cap was implemented in 1998-1999 with a closure report finalized in November 1999 (fourth bullet).

OT41/Bldg. 719.

- *Building 719 Investigation Summary Report, Dover Air Force Base, Delaware* (USACE, 1995).
- *Final Report on the Site Characterization at Building 719, Dover Air Force Base, Delaware* (TRW, 1996).
- *Final Report for Accelerated Anaerobic Bioremediation Pilot, Dover Air Force Base, Delaware* (RTDF, 2000).

- *Cometabolic Bio-venting Field Test Conducted at Dover Air Force Base,* Tech Trends, G. Sayles, EPA 542-N-00-005 August 2000, Issue No. 38.

The post-RI sampling of soil gas, soil, and groundwater (first two bullets) clearly identified Building 719 as a major source of chlorinated solvents, in particular the engine cleaning rooms near the north corner of the building. Two pilot tests were then conducted (bullets 3 and 4).

SS59.

- *Results of Lindane Source Area Investigation* (HAZWRAP, 1996).
- *Final Technical Memorandum, Lindane Source Characterization Investigation, December 1996 (Stage 2), Dover Air Force Base, Delaware* (HAZWRAP, 1997c).
- *Final Engineering Evaluation and Cost Analysis* [EECA], *Lindane Source Area, Dover Air Force Base, Delaware* (HAZWRAP, 1997b).
- *Target Area 1 – SS59 Site Investigation Summary Report, Dover Air Force Base, Delaware* (USACE, 1999a).

Several rounds of soil sampling were conducted to delineate the horizontal and vertical extent of pesticide-contaminated soils (first two bullets). The data confirmed that the pesticide contamination was predominantly in shallow soils of the open storage area. An EECA was then prepared to determine remediation options (third bullet). A 'hot-spot' soil removal and capping alternative was proposed in the EECA and approved by USEPA Region 3 and DNREC.

Confirmation soil samples were collected after the soil removal action (fourth bullet). Additional samples were collected just prior to capping. In both cases, residual pesticides were detected above RBCs at some locations. The overall conclusion, however, was that residual contaminants were generally limited to the shallow soils. All of the locations where residual pesticide concentrations exceeded an RBC were covered by the asphalt capping system.

Area 6.

- Various Technical Reports on Natural Attenuation Processes in Area 6 by the RTDF (reports dated circa 1997).
- *Summary Report Target Area 2 Delineation, Dover Air Force Base, Delaware* (USACE, 1997a).
- *Summary Report Source Characterization of Target Areas 2 and 3, Dover Air Force Base, Delaware* (USACE, 1999a).

As described in the FS for the WMU (USACE, 2005), the RTDF conducted a three-year comprehensive natural attenuation study of the Area 6 chlorinated solvent plume (first bullet). Eleven rounds of samples were collected from as many as 50 wells within the Area 6 plume. The RTDF studies included: a transect study which analyzed

groundwater chemistry data; characterization of microbiological organisms present in the aquifer; correlation of the microbial physiology and phylogeny with the biogeochemistry of the aquifer to provide microbiological evidence for natural attenuation; a geostatistical evaluation of the data; and a stable carbon isotope evaluation. Strong evidence for complete biodegradation of COCs in Area 6 was found, including:

- The presence of the degradation products cis-1,2 DCE, VC, and ethene;
- The presence of known anaerobic-halorespiring micro-organisms (naturally occurring);
- The presence of favorable groundwater geochemistry characteristics including depleted oxygen levels and strongly reducing environmental conditions;
- The presence of elevated methane and hydrogen concentrations;
- The presence of total organic carbon (TOC) in sufficient abundance in aquifer soils to support dehalogenation reactions.

However, the rate of degradation is not sufficient to prevent TCE from migrating southward, as evidenced by increasing TCE concentrations in several downgradient wells located south of U.S. Route 113 (Figure 2).

To better define the contributing sources to the Area 6 plume, groundwater was sampled during two projects (bullets 2 and 3). Target areas had been defined based on RI data, but actual sources had not been clearly identified. These sampling events revealed that two of the individual target areas (earlier labeled Target Areas 2 and 3) were actually both related to the release at OT41/Bldg. 719, and that this area merged with Target Area 1 originating in the vicinity of WP21. In the WMU FS, the Area 6 Proposed Plan, and this ROD, this combined source region is now referred to as Target Area 1,2,3. A second small source region within Area 6 was identified in the WMU FS as Target Area 6 (Figure 2).

2.4.6 Nature and Extent of Contamination

Data collected for the RI were combined with data from the previous studies to provide the basis for defining the nature and extent of contamination and risk assessments for the Area 6 sites. As mentioned in Section 2.4.5, additional data were later collected in 1999 at the SS59 soil removal action location, and in the mid 1990s for the natural attenuation study of the Area 6 groundwater plume. Brief summaries of the contamination assessment findings for each site are provided below. None of the chemicals detected in surface water and sediment at any of the sites failed the screening against benchmark levels; therefore, no contaminants are discussed for these media in the following paragraphs.

2.4.6.1 WP21

Soil samples collected during the 1993 RI and subsequent 1997 WP21 sampling event at the location of the former industrial waste lagoons were virtually free of contaminants. Additionally, during the 1998 remedial action, contaminated soil associated with the former concrete waste basins was excavated down to the groundwater table and sent off-site for treatment and disposal. Cleanup to below USEPA's Soil Screening Level for

Transfers from Soil to Groundwater (SSL_{gw}) was achieved during this action. Thus, all contaminated soil identified at WP21 has been remediated.

Groundwater contaminants and their maximum concentrations found during the RI are the chlorinated solvents 1,1,1-TCA (5,700 μg/L), 1,1-DCE (1,500 μg/L), cis-1,2-DCE (7,300 μg/L), PCE (710 μg/L), and TCE (1,600 μg/L). These VOCs exceeded federal MCLs. Lindane, a pesticide, also exceeded its MCL at a maximum concentration of 27.6 μg/L. One of its isomers is also present, alpha-BHC.

2.4.6.2 WP31

Soil samples collected during the RI were found to contain primarily residual petroleum-related contaminants and a few pesticides.

In groundwater, benzene and TCE are the primary concerns; both were present in three of the four samples collected at this site with maximum concentrations of 120 and 100 μg/L, respectively. Arsenic was present in only one of four samples and at a concentration well below it MCL.

2.4.6.3 ST34

None of the chemicals detected in soil at Site ST34 failed the screening benchmark or background levels; therefore, no contaminants were identified for the soil at ST34.

Fuel and chlorinated solvent contaminants were found in groundwater at this site. These contaminants (which exceeded federal MCLs), and their maximum concentrations found during the RI, are benzene (130 μg/L), 1,2-DCA (36 μg/L), cis-1,2-DCE (510 μg/L), PCE (1,200 μg/L), and TCE (3,400 μg/L). The pesticide Lindane (0.97 μg/L) also exceeded its MCL. It is present in a narrow plume in the middle of Area 6.

Antimony exceeded its MCL. However, it was present in only one sample of the 10 collected at this site and was not a concern at any of the other Area 6 sites. Arsenic was present in only one sample and was well below its MCL. Cadmium was slightly above its MCL in one of 10 samples.

2.4.6.4 OT41/Bldg. 719

RI soil sampling revealed only residual fuel and solvent contaminants. Later soil sampling prompted the selection of the area around the former USTs next to Building 719 for a demonstration of cometabolic bio-venting, which was conducted in 1997-1998 by the RTDF under a 1995 interim ROD (DAFB, 1995c). Cometabolic bio-venting is a soil treatment technology whereby air and a food source (in this case, propane) are injected into the soil, stimulating the naturally occurring bacteria that degrade chlorinated solvents. The RAO for the cometabolic bio-venting action was to reduce soil concentrations of each ethyl-based VOC by 90 percent from the maximum detected concentration. These objectives were met and exceeded, with most final concentrations

falling below detection limits (USEPA, 2000). The cometabolic bio-venting action treated the soil source next to Building 719, but did not treat the soil underneath the building. Based on the high level of groundwater contamination detected at Building 719, it was suspected that there might be a remaining soil source under the building near the drain lines from the former engine cleaning rooms. However, data from shallow soil samples collected underneath the building did not confirm the presence of a soil source, possibly because the samples were collected in an area where there is a thick gravel sub-base through which contaminants would have quickly passed.

OT41/Bldg. 719 is the single largest contributor of chlorinated solvents to the Area 6 groundwater plume. This site, a source of PCE, TCE, cis-1,2-DCE, and vinyl chloride, is at the upgradient edge of the Area 6 plume, where solvent concentrations in groundwater are at their highest. At the time of the RI, the maximum concentrations of the solvents were 2,000 μg/L of cis-1,2-DCE, 310 μg/L of PCE, 21,000 μg/L of TCE, and 14 μg/L of vinyl chloride.

Beryllium was a very minor contributor to the human health risks at this site. It was present at only 1.1 μg/L, which is well below its MCL, and in only one of five samples collected.

Per a 1995 interim ROD (DAFB, 1995b), treatment of the chlorinated solvent source underneath Building 719 began in 2002 and is ongoing. This treatment uses an AAB recirculation system, which is described in more detail in Section 2.8.1.9. Data collected during its operation show the system to be highly effective in treating the chlorinated solvents. The monitoring data also show that the system is treating not only the groundwater, but also residual soil contaminants underneath Bldg. 719 which are being flushed into the treatment zone as the water table fluctuates to within one foot of the building foundation.

2.4.6.5 OT48

Soil contaminants found during the RI were limited to primarily fuel components and pesticides.

Both fuel and solvent contaminants were found in groundwater at OT48. The fuel contaminant benzene (maximum concentration of 17 μg/L) exceeded its MCL in one sample and is limited to a small area in the shallow portion of the Columbia Aquifer. The chlorinated solvents TCE and vinyl chloride were found at maximum concentrations of 130 and 3 μg/L, respectively, both exceeding their MCLs.

Arsenic was found in only two of the six samples collected, and at concentrations well below its MCL.

2.4.6.6 SS59

Post-RI soil sampling revealed pesticides (DDD and DDT) in four hot-spots, which were the focus of a removal and capping action (see Section 2.8.1.10). A total of 147 tons of contaminated soil were removed. Confirmation sampling indicated that residual pesticides were still present (Table 1) and thus the area was covered with an asphalt capping system. Although not a problem in soil, another pesticide, Lindane, was found at a maximum concentration of 38 µg/L (exceeding its MCL) and is present in a narrow groundwater plume in the center of Area 6.

Table 1. Pesticides in Soil at SS59 (Post-Removal Action)

Soil Contaminants	Maximum Detected Concentration (µg/kg)	Screening Criterion (µg/kg)(1)
DDD	540,000	24,000
DDT	540,000	17,000

(1) USEPA Region 3, risk-based screening criterion (RBSC), circa 1997.
DDD = dichlorodiphenyldichloroethane
DDT = dichlorodphenyltrichloroethane
µg/kg = micrograms per kilogram

2.4.6.7 OT28

Few contaminants were detected in soil during the RI. Two chlorinated solvents, carbon tetrachloride and TCE, were found to be a concern in groundwater with maximum concentrations of 19 and 120 µg/L, respectively. Although OT28 is a suspected minor source, groundwater data suggest that contaminants migrating from upgradient sites within Area 6 are also affecting the site. This is confirmed by data from the ongoing natural attenuation monitoring within part of Area 6.

Dieldrin was also detected in the groundwater at this site and its presence is considered typical of that found across the Base, reflecting its past use for pest control rather than a site-related waste.

2.4.6.8 Area 6

Area 6 is defined by the distribution of commingling contaminants in the Columbia Aquifer originating from the sites previously discussed. The predominant contaminants are the various chlorinated solvents detected at the individual sites. Two other contaminants are the fuel-related contaminant benzene, and Lindane (a pesticide). Alpha-BHC is an isomer of Lindane and is also present in groundwater.

Target areas within the Area 6 plume were used in the WMU FS to assist with the evaluation of remediation options. Target areas are regions of the most elevated contaminant concentrations detected in the Columbia Aquifer, i.e., source areas. There are two target areas within the encompassing Area 6 groundwater plume: Target Area 1,2,3 and Target Area 6 (Figure 2). Target Area 1,2,3 encompasses four sites in close

proximity to one another (OT41/Bldg. 719, WP21, SS59, and ST34) and forms the core of the Area 6 plume. Target Area 1,2,3 is approximately 800 ft wide by 4,600 ft long. Target Area 6 is much smaller and is a few hundred yards to the east of Target Area 1,2,3. It is about 400 ft wide by 1,600 ft long. WP31 and OT48 are minor contributors at the upgradient edge of the Area 6 plume. Similarly, the former waste water treatment plant at OT28 is at the downgradient edge of Area 6. In general, the contaminants are present in the shallow groundwater at the upgradient portion of the target areas and they move deeper within the aquifer as they migrate downgradient.

2.5 CURRENT AND POTENTIAL FUTURE LAND AND WATER USES

2.5.1 Land Use

Current On-Site Land Use. Current land use on DAFB includes both industrial and residential areas. The largest portion of the Base is the industrial area which includes taxiways and runways, aircraft hangars, maintenance and support facilities. The industrial portion of the Base is completely enclosed by a security fence. It is only accessible to authorized personnel through manned security gates; it is not accessible to the general public. The residential area is on the southwest side of the Base and includes a military family housing area, golf course, and military dependents school. Six of the seven Area 6 sites are located in the industrial area of the Base. OT28 is adjacent to the Base housing area in the residential portion of the Base. It is fenced and has a locked gate. None of the seven sites are accessible to the general public.

Current Adjacent/Surrounding Land Use. Land uses in the vicinity of DAFB include single and multifamily residential areas, industrial zones, commercial land located along major highways, and extensive areas of agricultural and open land. There are two large concentrations of industrial areas located just north of DAFB.

Reasonably Anticipated Future Land Use. The Base has operated as an airport since 1941. Due to its mission of providing critical air lift capabilities and serving as the joint services port mortuary, the projected land use of DAFB is to remain an active airfield for the foreseeable future. The six sites in the industrial area are highly unlikely to be developed for non-industrial purposes for the foreseeable future. OT28 is currently an open storage area used to store non-hazardous construction materials. Due to its location near Base housing, future residential development is possible at this site.

2.5.2 Surface Water Uses

Current Surface Water Use. There is one main surface water body associated with the Area 6 sites in the WMU: the St. Jones River (Figure 1). The river is used for recreational purposes, primarily fishing, but is not used for potable water. The State of Delaware does not classify the St. Jones River as a potable water source. The golf course tributary is a small secondary surface water body that drains stormwater runoff from the southwest edge of the WMU and discharges into the St. Jones River. The golf course tributary is too small to support recreational use, and its only use is as a drainage ditch.

Potential Beneficial Surface Water Use. The anticipated future use of the St. Jones River is for recreational purposes, as classified by the State of Delaware. It is not expected to be used as a potable water source because the Base and surrounding communities derive their drinking water from groundwater. Consequently, the beneficial use of the St. Jones River is not expected to change from its current recreational use.

2.5.3 Groundwater Use

Current Groundwater Use. Groundwater from the surficial (Columbia) aquifer is not used at DAFB. DAFB obtains potable water from several deep supply wells installed either in the Cheswold or Piney Point Aquifers (see Section 2.4.2). However, the State of Delaware considers all aquifers potential sources of drinking water and the Columbia Aquifer is used by the surrounding community. Moreover, the Columbia Aquifer would be considered as a Class IIA aquifer, a currently used source of drinking water, based on Guidelines for Ground-Water Classification under the EPA Ground-Water Protection Strategy. Off-Base, the Columbia Aquifer is used predominantly for irrigation and domestic supply. To date, there is no evidence that DAFB has adversely affected off-Base groundwater quality southwest of the Base, which is the direction of groundwater flow from Area 6.

In 2003, DNREC established a GMZ encompassing DAFB, the region between the Base and the St. Jones River, and a small area next to the Base near the Pipe Elm Branch. The GMZ prohibits unauthorized use of the Columbia Aquifer in these areas and is enforced through DNREC's well permitting process (DNREC, 2003). There are currently no Columbia Aquifer production wells in the downgradient vicinity of Area 6 that could be affected by the contaminant plume.

Potential Beneficial Groundwater Use. Potential beneficial use of the Columbia Aquifer is as a drinking water source.

2.6 SUMMARY OF SITE RISKS

This section presents the assessment methods and results for both human health and ecological risk assessments.

2.6.1 Summary of Human Health Risk Assessment

As part of the Basewide RI a Baseline Risk Assessment was conducted. The Baseline Risk Assessment estimates what risks sites pose if no action is taken. It provides the basis for taking action and identifies what contaminants and exposure pathways, if any, need to be addressed by a remedial action. The risk assessment focused on potential pathways in which Base personnel, maintenance and construction workers, and, for one site, Base residents could be exposed to contaminated materials originating at each site. The risk assessment is summarized below.

2.6.1.1 Identification of COCs

Human health risks from exposure to soil, groundwater, surface water, and sediment were assessed in the Basewide RI (USACE, 1994 and 1997). Contaminants of potential concern (COPCs) were identified using both the historic and the Basewide RI data by comparing the maximum detected concentration of a chemical in each media to its RBSC in accordance with USEPA Region 3 guidance (USEPA, 1993). RBSCs are generally very conservative values used as the first screening benchmark in the risk assessment process. Any chemical whose concentration either exceeded its RBSC, or for which no RBSC was available, was identified as a site-related COPC for that medium and was retained for further evaluation during the risk assessment. The RBSCs were developed according to USEPA Region 3 protocols using standard exposure pathways and available toxicity criteria. The COPCs identified during this initial screening process were then evaluated for human health risks as described in sections 2.6.1.2 through 2.6.1.4. As a result of the Basewide RI risk evaluation, contaminants found to contribute to an elevated human health risk were identified as COCs. Contaminants with the potential to migrate off-Base at levels exceeding MCLs were added to the COC list based on the RI data discussed in Section 2.4.6.

Table 2 lists the groundwater contaminants for each site, their maximum detected concentrations, and the federal drinking water MCLs. The data listed for Area 6 are a combination of data collected at the individual sites with data obtained specifically for Area 6 as a whole. Contaminants are listed in Table 2 for one of two reasons, or both: (1) by exceeding a groundwater MCL, and/or (2) by contributing to overall human health risks. In some instances, contaminants have been determined not to be COCs, and these instances are explained for each site in the subsequent discussion.

Table 2. Area 6 Site Contamination Summary

Groundwater Contaminant	Maximum Detected Concentration (µg/L)	MCL (µg/L)
WP21		
1,1,1-TCA	5,700	200
1,1-DCE[1]	1,500	7
cis-1,2,-DCE[1]	7,300	70
PCE	710	5
TCE[1]	1,600	5
Alpha-BHC[1]	16	--
Lindane[1]	27.6	0.2
Manganese[1, 2]	4,760	--
WP31		
Benzene[1]	120	5
TCE[1]	100	5
Arsenic[1, 2]	4.5	50
Manganese[1, 2]	447	--

Table 2. Area 6 Site Contamination Summary (cont'd)

Groundwater Contaminant	Maximum Detected Concentration (μg/L)	MCL (μg/L)
ST34		
1,2-DCA[1]	36	7
cis-1,2-DCE	510	70
Benzene[1]	130	5
PCE[1]	1,200	5
TCE[1]	3,400	5
Lindane	0.97	0.2
Antimony[1, 2]	38.6	6
Arsenic[1, 2]	3.1	50
Cadmium[2]	5.4	5
Manganese[1, 2]	657	--
OT41/Bldg. 719		
cis-1,2-DCE[1]	2,000	70
PCE[1]	310	5
TCE[1]	21,000	5
Vinyl chloride[1]	14	2
Beryllium[1, 2]	1.1	4
OT48		
Benzene[1]	17	5
TCE	130	5
Vinyl chloride[1]	3	2
Arsenic[1, 2]	9.5	50
Manganese[1, 2]	870	--
SS59 – See Area 6		
OT28		
Carbon tetrachloride[1]	19	5
TCE[1]	120	5
Dieldrin[1, 2]	0.26	--
Area 6		
Benzene[1]	6,100	5
1,1,1-TCA	5,700	200
1,1-DCE	1,500	7
1,2-DCA[1]	740	5
cis-1,2-DCE[1]	7,300	70
Carbon tetrachloride[1]	480	5
PCE[1]	1,200	5
TCE[1]	21,000	5
Vinyl chloride[1]	180	2
Alpha-BHC[1]	21	--
Lindane[1]	38	0.2
Antimony[1, 2]	38.6	6
Arsenic[1, 2]	9.5	50
Manganese[1, 2]	4,760	--

DCA = dichloroethane
DCE = dichloroethene
PCE = tetrachloroethene or perchloroethene
μg/L = micrograms per liter

(1) This contaminant is a partial contributor to human health risks as determined during the Basewide RI.
(2) Although this contaminant contributed to the human health risks, it was eliminated as a COC for the reasons discussed below.

Table 3 is the initial list of COCs identified for each site and medium, their detected concentration ranges, detection frequencies, and exposure point concentrations (EPCs). No COCs were identified in surface water or sediment at any of the sites in this ROD. There were no unacceptable risks from exposure to chemicals in soils at the sites in this ROD, with the exception of pesticides at Site SS59, therefore no COCs were identified for the soils, except at Site SS59. The development and use of EPCs in the exposure assessment portion of the risk assessment is discussed in the following section.

Several site contaminants were determined not to be COCs. These specific instances are described below.

- Manganese was determined to be a partial contributor to the human health risk at WP21, WP31, ST34, OT48, and Area 6. However, manganese is elevated in groundwater because it has been mobilized from the soil in reaction to contamination that has changed the aquifer chemistry. This soluble manganese is not itself a contaminant from a waste release but a temporary by-product that will naturally revert to its insoluble state once the contamination has been remediated and the aquifer chemistry returns to normal. Thus, manganese is not a site-related COC and does not require specific action.

- Arsenic was present in only one of the four samples at WP31, and at a concentration well below its MCL. Therefore, action is not required for arsenic and it is eliminated as a COC.

- Arsenic was present in only one sample at ST34 and was well below its MCL; therefore it is not a COC.

- Arsenic was found in only two of the six samples collected at OT48, and at concentrations well below its MCL. It was eliminated as a COC.

- Antimony was present in only one sample of the 10 collected at ST34 and was not a concern at any of the other Area 6 sites. It was eliminated as a COC.

- Cadmium was slightly above its MCL in one of the 10 samples at ST34 and was not a contributor to risk. Thus, it was eliminated as a COC.

- Beryllium was a very minor contributor to human health risks at OT41/Bldg. 719. It was present at only 1.1 μg/L, which is well below its MCL, and in only one of five samples collected. It was eliminated as a COC.

- Dieldrin was a partial contributor to human health risks from groundwater at OT28. However, its presence is considered typical of that found across the Base, reflecting its past use for pest control rather than a site-related waste. Thus it was eliminated as a COC.

Table 3. Human Health COC Summary

Groundwater COCs	Concentration Range (µg/L)	Detection Frequency (positive detections/ number of samples)	EPC (µg/L); all values are the 95% UCLs unless noted otherwise
WP21			
1,1,1-TCA[2]	1 - 5,700	7 / 14	2,210
1,1-DCE[1,2]	15 - 1,500	4 / 14	600
cis-1,2-DCE[1,2]	31 - 7,300	8 / 14	3,440
PCE[2]	1 - 710	9 / 14	239
TCE[1,2]	13 - 1,600	8 / 14	495
Alpha-BHC[1]	0.061 - 16	2 / 8	8.73
Lindane[1,2]	0.36 - 27.6	2 / 8	13.2
Manganese[1]	3.1 - 4,760	19 / 19	890
WP31			
Benzene[1,2]	17 - 120	3 / 4	105
TCE[1,2]	2 - 100	3 / 4	91.4
Arsenic[1]	4.5	1 / 4	4.01
Manganese[1]	290 - 447	4 / 4	435
ST34			
Benzene[1,2]	2 - 130	4 / 10	78.6
1,2-DCA[1,2]	3 - 36	3 / 10	35
cis-1,2-DCE[2]	2 - 510	10 / 10	196
PCE[1,2]	1 - 1,200	7 / 10	445
TCE[1,2]	4 - 3,400	10 / 10	1,260
Lindane[2]	0.023 - 0.97	2 / 2	0.97 (max)
Antimony[1,2]	38.6	1 / 10	23.4
Arsenic[1]	3.1	1 / 10	1.95
Cadmium[2]	5.4	1 / 10	3.32
Manganese[1]	30.3 - 657	10 / 10	250
OT41/Bldg. 719			
cis-1,2-DCE[1,2]	5 - 2,000	5 / 6	1,420
PCE[1,2]	2 - 310	3 / 6	300
TCE[1,2]	3 - 21,000	5 / 6	8,000
Vinyl chloride[1,2]	14	1 / 6	14 (max)
Beryllium[1]	1.1	1 / 5	0.876
OT48			
Benzene[1,2]	17	1 / 6	17 (max)
TCE[2]	10 - 130	3 / 6	68.8
Vinyl Chloride[1,2]	1 - 3	2 / 6	3 (max)
Arsenic[1]	4.8 - 9.5	2 / 6	5.75
Manganese[1]	79.2 - 870	6 / 6	60.3
SS59 (included with Area 6)			

Table 3. Human Health COC Summary (cont'd)

Groundwater COCs	Concentration Range (µg/L)	Detection Frequency (positive detections/ number of samples)	EPC (µg/L); all values are the 95% UCLs unless noted otherwise
OT28			
Carbon tetrachloride[1,2]	2 - 19	4 / 6	9.39
TCE[1,2]	9 - 120	4 / 6	54.8
Dieldrin[1]	0.048 - 0.26	10 / 10	0.20
Area 6*			
Benzene[1,2]	2 - 6,100	7 / 54	225
1,1,1-TCA[2]	(see WP21)	(see WP21)	172
1,1-DCE[1,2*]	1 - 58	4 / 54	65.4
1,2-DCA[1,2]	1 - 740	7 / 54	42.7
cis-1,2-DCE[1,2*]	0.8 - 2,600	23 / 54	323
PCE[1,2*]	0.5 - 1,000	18 / 54	107
TCE[1,2*]	0.5 - 15,000	34 / 54	874
Carbon tetrachloride[1,2]	1 - 480	11 / 54	45.5
Vinyl chloride[1,2]	2 - 180	2 / 54	48.9
Alpha-BHC[1]	0.0004 - 21	12 / 22	1.72
Lindane[1,2]	0.0007 - 38	7 / 22	3.21
Antimony[1,2]	(see ST34)	(see ST34)	18.2
Arsenic[1]	(see OT48)	(see OT48)	1.89
Manganese[1]	(see WP21)	(see WP21)	339

[1]COC identified based on Basewide RI risk assessment.

[2]COC exceeded federal drinking water MCL.

(max): EPC is the maximum detected concentration.

*Concentration ranges and detection frequencies were based on the 54 samples specific to the delineation of the Area 6 plume. Several compounds have a different maximum concentration than shown in Table 2 because the data set used for Table 2 was larger. The EPC for the risk assessment was calculated using the Area 6 data combined with the data from associated sites.

2.6.1.2 Exposure Assessment

The exposure assessment is a process of characterizing the exposure setting, identifying exposure points and pathways (i.e., routes by which COPCs pass from contaminated media to human receptors), and quantifying exposure. The Site Conceptual Model (Section 2.4.1) is used to determine reasonable exposure scenarios and pathways of concern. Routes of exposure are based on the current, future, and, in some cases, hypothetical land and groundwater uses (see Section 2.5).

Identification of Exposure Scenarios. It is assumed that current Base workers can be exposed to residual contaminants in the surface and subsurface soil during regular maintenance activities (e.g., utility installation or repair). Potential risks associated with the current workers' exposure to contaminants in groundwater are not calculated, because groundwater from the Columbia Aquifer is not currently being used anywhere on Base. It is assumed that future on-site workers can be exposed to residual contaminants in soil through construction or excavation activities. A hypothetical future commercial/

industrial groundwater use was also assumed such that: (1) there are commercial/ industrial users located on Base who will use the Columbia Aquifer in the future as a source of water for drinking and showering, and (2) concentrations detected during the Basewide RI on or near the site represent the concentrations to which these users may be exposed (USACE, 1994 and1997). One site (OT28) is located near the Base housing area. For this site, residential exposures were also assessed. The receptors and exposure pathways used in the Baseline Risk Assessment are:

- Current and future commercial/industrial exposure to an on-Base worker through inhalation and ingestion of soil during construction or excavation.
- Hypothetical future commercial/industrial exposure to an on-Base worker through inhalation and ingestion of groundwater.
- Residential exposure at Site OT28 located near the Base housing area through ingestion and inhalation of soil and groundwater by children and adults.

Quantification of Exposure Point Concentrations (EPCs). EPCs are calculated by estimating the 95 percent upper confidence limit (UCL) on the arithmetic mean concentration for each COPC. Where the calculated EPC exceeds the COPC's maximum concentration, the maximum concentration is used as the EPC in the risk assessment. EPCs for the COCs are listed in Table 3.

2.6.1.3 Toxicity Assessment

The objective of the toxicity assessment is to evaluate available information regarding the potential for COPCs to cause adverse health effects in exposed individuals, and to provide the analytical framework for the characterization of human health impacts. The toxicity assessment summarizes published data on human health effects. This includes quantitative reference doses (RfD) for noncarcinogenic effects (health problems other than cancer) and slope factors (SF) for carcinogenic (cancer) effects. RfDs represent the maximum acceptable uptake of noncarcinogens by humans, expressed in milligrams of chemical per kilogram of body weight per day. SFs are quantitative estimates of the increased probability of cancer developing in an exposed individual. SFs are expressed as the lifetime cancer risk per milligram of chemical per kilogram of body weight per day. A summary of the toxicity data for Area 6 COCs is included in Table 4.

2.6.1.4 Risk Characterization

The final step of the baseline risk assessment, risk characterization, consists of quantitative estimates of carcinogenic risk and noncarcinogenic hazard, which are derived by relating estimated intakes to toxicity criteria. Carcinogenic risks and noncarcinogenic hazards are quantified for each contaminant. The terms "lifetime excess cancer risk" (LECR) and "hazard index" (HI) are used to refer to carcinogenic and noncarcinogenic health effects, respectively.

Table 4. Cancer and Non-Cancer Toxicity Data Summary

	Cancer Toxicity Data				Non-Cancer Toxicity Data			
COC	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight of Evidence/Cancer Guideline Description	Source	Oral Reference Dose (mg/kg-day)	Dermal Reference Dose (mg/kg-day)	Primary Target Organs/Uncertainty Factor (UF)	Source
Groundwater								
Pathway: Ingestion								
1,1-DCE	0.60	*	C	IRIS	9×10^{-3}	*	Liver, UF = 1000	HEAST
1,2-DCA	0.091	*	B2	IRIS		*		
1,2-DCE		*	D	IRIS	9×10^{-3}	*	Liver, UF = 1000	HEAST
Benzene	0.029	*	A	IRIS		*		
Carbon tetrachloride	0.13	*	B2	IRIS	7×10^{-4}	*	Liver; UF = 1000	IRIS
PCE	0.05	*	B2	HEAST	1×10^{-2}	*	Hepatotoxicity; UF = 1000	IRIS
TCE	0.01	*	B2	HEAST	6×10^{-3}	*	Hepatotoxicity	Region III
Vinyl chloride	1.90	*	A	HEAST		*		
Alpha-BHC	6.2	*	B2	IRIS		*		
Dieldrin	16.0	*	B2	IRIS	5×10^{-5}	*	Liver; UF = 100	HEAST
Lindane	1.3	*	B2 - C	HEAST	3×10^{-4}	*	Liver, kidney, UF = 1000	IRIS
Antimony		*			4×10^{-4}	*	Increased mortality, UF = 1000	IRIS
Arsenic	1.75	*	A	IRIS	3×10^{-4}	*	skin, vascular complications, UF = 3	IRIS
Beryllium	4.3	*	B2	IRIS	5×10^{-3}	*	No adverse effects; UF = 100	IRIS
Manganese		*	D	IRIS	5×10^{-3}		nervous system, UF = 1	IRIS

Table 4. Cancer and Non-Cancer Toxicity Data Summary (continued)

	Cancer Toxicity Data				Non-Cancer Toxicity Data			
COC	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Dermal Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Weight of Evidence/Cancer Guideline Description	Source	Oral Reference Dose (mg/kg-day)	Dermal Reference Dose (mg/kg-day)	Primary Target Organs/Uncertainty Factor (UF)	Source
Pathway: Inhalation								
1,1-DCE	0.175	*	C	IRIS		*		
1,2-DCA	0.091	*	B2	IRIS	2.86×10^{-3}	*		Region III
1,2-DCE		*	D	IRIS		*		
Benzene	0.029	*	A	IRIS	1.43×10^{-4}	*		Region III
Carbon tetrachloride	0.053	*	B2	HEAST	5.71×10^{-4}	*		Region III
PCE	0.001	*	B2	Region III		*		
TCE	0.006	*	B2	Region III		*		
Vinyl chloride	0.3	*	A	HEAST		*		
Alpha-BHC	6.3	*	B2	IRIS		*		
Dieldrin	16.1	*	B2	IRIS		*		
Lindane		*				*		
Antimony		*				*		
Arsenic	1.51E+01	*	A	IRIS		*		
Beryllium	8.40E+00	*	B2	IRIS		*		
Manganese		*	D	IRIS	1.43×10^{-5}	*	respiratory and psychomotor effects, UF = 300	IRIS

*Dermal exposure was not evaluated.

Empty portions of the table reflect that this data was not available at the time of the Basewide RI risk assessment.

UF = uncertainty factor, listed where available. The higher this value, the greater the uncertainty in the estimation of toxic effects on human health.

Source:

IRIS, Integrated Risk Information Management System, 1995

HEAST, Health Effects Assessment Summary Tables, 1994

USEPA, U.S. Environmental Protection Agency, Risk-Based Concentration Tables, 1994

Cancer Guideline Description:

A - Human carcinogen

B1 - Probable human carcinogen, limited human data available

B2 - Probable human carcinogen, sufficient data for animals, insufficient data for humans

C - Possible human carcinogen, limited data for animals

D - Not classifiable as a human carcinogen

For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

$$LECR = CDI \times SF$$

where:

LECR = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
SF = slope factor, expressed as $(mg/kg\text{-}day)^{-1}$

These risks are probabilities that usually are expressed in scientific notation (e.g., 1×10^{-6}). An excess lifetime cancer risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The chance of an individual developing cancer from all other causes has been estimated to be as high as one in three. According to EPA guidance, the generally acceptable LECR range for site-related exposures is 1×10^{-4} to 10^{-6}. The risk characterization for carcinogens at the Area 6 sites is summarized in Table 5.

The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., life-time) with an RfD derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An HQ<1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The HI is generated by adding the HQs for all COCs that affect the same target organ (e.g., liver) or that have some other critical effect such as reproductive toxicity. An HI<1 indicates that, based on the sum of all HQs from different contaminants and exposure routes, toxic noncarcinogenic effects from all contaminants are unlikely. An HI≥1 indicates that site-related exposures may present a risk to human health. The HQ is calculated as follows:

$$HQ = CDI/RfD$$

where: CDI = chronic daily intake
RfD = reference dose

CDI and RfD are expressed in the same units and represent the same exposure period (i.e. chronic, subchronic, or short-term). The risk characterization for non-carcinogens at the Area 6 sites is summarized in Table 5.

Table 5. Risk Characterization Summary Highlights

WP21 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,1-DCE	1×10^{-3}	5×10^{-4}	2×10^{-3}	0.7			0.7
1,2-DCE				4			4
TCE	2×10^{-5}	1×10^{-5}	3×10^{-5}	1			1
Alpha BHC	2×10^{-4}	4×10^{-6}	2×10^{-4}				
Lindane	6×10^{-5}		6×10^{-5}	0.4			0.4
Manganese				2			2
WP21 groundwater risk total[(1)] =			2×10^{-3}	WP21 groundwater hazard total =			8

WP31 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
Benzene	1×10^{-5}	1×10^{-5}	2×10^{-5}		9		9
TCE	4×10^{-6}	2×10^{-6}	6×10^{-6}	0.2			0.2
Arsenic	3×10^{-5}		3×10^{-5}	0.1			0.1
Manganese				0.9			0.9
WP31 groundwater risk total[(1)] =			6×10^{-5}	WP31 groundwater hazard total =			10

ST34 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,2-DCA	1×10^{-5}	1×10^{-5}	2×10^{-5}		0.1		0.1
Benzene	8×10^{-6}	1×10^{-5}	2×10^{-5}	0.2	7		7
PCE	8×10^{-5}	3×10^{-6}	8×10^{-5}	0.4			0.4
TCE	5×10^{-5}	3×10^{-5}	8×10^{-5}	2			2
Antimony				0.6			0.6
Arsenic	1×10^{-5}		1×10^{-5}	0.06			0.06
Manganese				0.5			0.5
ST34 groundwater risk total[(1)] =			3×10^{-4}	ST34 groundwater hazard total =			11

Table 5. Risk Characterization Summary Highlights (continued)

OT41/Blgd. 719 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,2-DCE				2			2
PCE	6×10^{-5}	2×10^{-6}	6×10^{-5}	0.3			0.3
TCE	3×10^{-4}	2×10^{-4}	5×10^{-4}	13			13
Vinyl chloride	9×10^{-5}	2×10^{-5}	1×10^{-4}				
Beryllium	1×10^{-5}		1×10^{-5}	0.002			0.002
OT41/Blgd. 719 groundwater risk total[1] =			7×10^{-4}	OT41/719 groundwater hazard total =			15

OT48 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
Benzene	2×10^{-6}	2×10^{-6}	4×10^{-6}				
Vinyl chloride	2×10^{-5}	5×10^{-6}	3×10^{-5}		2		2
Arsenic	4×10^{-5}		4×10^{-5}	0.2			0.2
Manganese				1			1
OT48 groundwater risk total[1] =			7×10^{-5}	OT48 groundwater hazard total =			3

SS59 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

Groundwater for SS59 was evaluated with Area 6.

OT28 Groundwater, Ingestion & Inhalation
Residential (adult)

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
Carbon tetrachloride	2×10^{-5}	5×10^{-6}	3×10^{-5}	0.5	0.4		1
TCE	9×10^{-6}	4×10^{-6}	1×10^{-5}	0.3			0.3
Dieldrin	5×10^{-5}	5×10^{-6}	5×10^{-5}	0.1			0.1
OT28 groundwater risk (adult) total[1] =			1×10^{-4}	OT28 groundwater hazard (adult) total =			1

Table 5. Risk Characterization Summary Highlights (continued)

OT28 Groundwater, Ingestion & Inhalation
Residential (child)*

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,2-DCA	Carcinogenic risk evaluated over a life time, thus the adult scenario accounts for the time spent as a child.				0.06		0.06
Carbon tetrachloride				0.9	0.9		2
TCE				0.6			0.6
Dieldrin				0.3			0.3
OT28 groundwater risk (child) total =			NA	OT28 groundwater hazard (child) total =			3

OT28 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,2-DCA	1×10^{-6}	1×10^{-6}	3×10^{-6}		0.01		0.01
Carbon tetrachloride	4×10^{-6}	2×10^{-6}	6×10^{-6}	0.1	0.2		0.3
TCE	2×10^{-6}	1×10^{-6}	3×10^{-6}	0.09			0.09
Dieldrin	1×10^{-5}	2×10^{-6}	1×10^{-5}	0.04			0.04
OT28 groundwater risk total =			3×10^{-5}	OT28 groundwater hazard total =			<1

Area 6 Groundwater, Ingestion & Inhalation
Future Hypothetical Commercial/Industrial

	Carcinogenic Risk			Non-Carcinogenic Hazard			
COC	Ingestion	Inhalation	Total	Ingestion	Inhalation	Primary Target Organ	Total
1,1-DCE	1×10^{-4}	5×10^{-5}	2×10^{-4}	0.07			0.07
1,2-DCA	1×10^{-5}	1×10^{-5}	2×10^{-5}		0.2		0.2
1,2-DCE				0.4			0.4
Benzene	2×10^{-5}	3×10^{-5}	5×10^{-5}		20		20
Carbon tetrachloride	2×10^{-5}	9×10^{-6}	3×10^{-5}	0.6	0.8		1
PCE	2×10^{-5}	8×10^{-7}	2×10^{-5}	0.1			0.1
TCE	3×10^{-5}	2×10^{-5}	5×10^{-5}	1			1
Vinyl chloride	3×10^{-4}	7×10^{-5}	4×10^{-4}				
Alpha BHC	4×10^{-5}	7×10^{-7}	4×10^{-5}				
Lindane	2×10^{-5}		2×10^{-5}	0.1			0.1
Antimony				0.5			0.5
Arsenic	1×10^{-5}		1×10^{-5}	0.06			0.06
Manganese				0.7			0.7
Area 6 groundwater risk total[(1)] =			9×10^{-4}	Area 6 groundwater hazard total =			25

NOTES:

[(1)]Total risks and hazard values are the sum of all COPCs that were retained from the initial screening and for which toxicity data were available. This table lists only those contaminants that contributed significantly to the total. Thus, the total may not precisely match the sum of the COCs due to the omission of low level COPCs and to rounding the total to one significant figure. Additionally, although listed here, some contaminants are not COCs. The various reasons for this are discussed in the text for each site.

To evaluate the total risk for the site, the LECR and HI values are summed for all contaminants for each pathway. The numerical results are compared to USEPA comparison criteria to determine if risks are present that warrant action. The USEPA comparison criteria are 1×10^{-4} for the LECR and 1 for the HI. USEPA guidance states that "where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 1×10^{-4}, and the noncarcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts. However, if MCLs or non-zero MCLGs are exceeded, action is generally warranted." (USEPA, 1991).

Table 6 summarizes the carcinogenic and non-carcinogenic human health risk values for each exposure pathway at the Area 6 sites. As shown in the table, the total HI values for all soil exposure scenarios are less than the USEPA comparison criterion of 1. Also, the total LECR values for all soil exposure scenarios are less than the USEPA comparison criterion of 1×10^{-4}. Thus, under the exposure scenarios evaluated, there are no unacceptable health risks for the soil medium at any of the Area 6 sites.

For groundwater, each site had an HI for site workers (commercial/industrial scenario) above the USEPA criterion of 1 (except OT28), and the LECRs were above the USEPA's criterion for every site except WP31, OT48, and OT28. For OT28 groundwater, the HI and LECR values equaled or exceeded the USEPA comparison criteria only under the residential scenario.

In addition to these human health risks, the Area 6 plume has the potential to migrate off-Base at concentrations exceeding the federal MCLs. Since the Columbia Aquifer is used by the surrounding community for irrigation and domestic supply, off-Base migration of contamination exceeding MCLs is an adverse environmental condition that requires action. Thus, based on the results of the human health risk assessment and the potential for off-Base migration of contamination, action is warranted to address groundwater contamination at Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28, and the Area 6 plume as a whole.

The results of the risk calculations contain an inherent level of uncertainty due to the various assumptions made and gaps in our knowledge on the particular health effects of some chemicals. The major sources of uncertainty and whether these are expected to under- or overestimate the potential risk are highlighted here:

- All sampling programs can only partially characterize a site. Although extensive data have been collected at the Area 6 sites, it is possible that some contamination has been missed. This may cause the risk to be underestimated.
- Toxicity data for some of the contaminants may not exist. Thus, these contaminants are not considered in the final risk values, which would be underestimated.

Table 6. Risk Characterization Comprehensive Summary

Site/Receptor	Soil Ingestion	Soil Inhalation	Groundwater Ingestion	Groundwater Inhalation	Total (1)
WP21 - HI					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	8	NQR	8
WP21 - LECR					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	2×10^{-3}	4.7×10^{-4}	2×10^{-3}
WP31 - HI					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	1.2	9.2	10
WP31 - LECR					
on-site worker, current	1×10^{-7}	7×10^{-12}	--	--	1×10^{-7}
on-site worker, future	2×10^{-6}	3×10^{-10}	4×10^{-5}	2×10^{-5}	6×10^{-5}
ST34 - HI					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	4	7	11
ST34 - LECR					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	2×10^{-4}	6×10^{-5}	3×10^{-4}
OT41/Bldg. 719 - HI					
on-site worker, current	5×10^{-4}	NQR	--	--	5×10^{-4}
on-site worker, future	0.1	NQR	15	0.2	15
OT41/Bldg. 719 - LECR					
on-site worker, current	2×10^{-7}	8×10^{-11}	--	--	2×10^{-7}
on-site worker, future	4×10^{-6}	7×10^{-9}	5×10^{-4}	2×10^{-4}	7×10^{-4}
OT48 - HI					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	1	2	3
OT48 - LECR					
on-site worker, current	3×10^{-8}	2×10^{-12}	--	--	3×10^{-8}
on-site worker, future	5×10^{-7}	9×10^{-11}	6×10^{-5}	8×10^{-6}	7×10^{-5}

Table 6. Risk Characterization Comprehensive Summary (continued)

Site/Receptor	Soil		Groundwater		
	Ingestion	Inhalation	Ingestion	Inhalation	Total (1)
SS59 - HI					
on-site worker, current	6×10^{-4}	NQR	--	--	6×10^{-4}
on-site worker, future	0.1	NQR	Assessed as part of Area 6		0.1
SS59 - LECR					
on-site worker, current	3×10^{-7}	9×10^{-11}	--	--	3×10^{-7}
on-site worker, future	6×10^{-6}	8×10^{-9}	Assessed as part of Area 6		6×10^{-6}
OT28 - HI					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	0.3	0.2	0.5
adult resident	0.06	NQR	1	0.4	1
child resident	0.2	NQR	2	0.9	3
OT28 - LECR					
on-site worker, current	NQR	NQR	--	--	NQR
on-site worker, future	NQR	NQR	2×10^{-5}	7×10^{-6}	3×10^{-5}
adult resident	NQR	NQR	9×10^{-5}	2×10^{-5}	1×10^{-4}
child resident	NQR	NQR	--	--	--
Area 6 Groundwater - HI					
on-site worker, current	--	--	--	--	--
on-site worker, future	--	--	4	21	25
Area 6 Groundwater - LECR					
on-site worker, current	--	--	--	--	--
on-site worker, future	--	--	7×10^{-4}	2×10^{-4}	9×10^{-4}

(1) Summation of values for all media
NQR - No quantifiable risk
-- Not a valid receptor/pathway

- For estimates of future risk, the contaminant concentrations were assumed to be the same as current levels. Over time, it is more likely that there would be some degradation or attenuation of contaminants. Thus, the future risks may be overestimated.
- Dermal exposures were not estimated for any media. Excluding this pathway may have underestimated site cancer risks and non-cancer hazards.
- Since the risk assessment was conducted in 1993-1994, some of the toxicity factors (shown in Table 4) have changed. In general, the values have become more restrictive indicating that the originally calculated risks and hazards are likely underestimated. Thus, there is some potential for EPA comparison criteria to be exceeded at sites currently below those levels.

The final list of COCs that warrant action was determined by taking several factors into consideration: site risks, exceedance of groundwater MCLs, the nature and extent of contamination at each site, off-Base plume migration, and, lastly, the potential breakdown products of the primary COCs if such breakdown products were not already identified at the site. Considering these factors, the following additions and deletions were made to the human health COC list shown in Table 3, to determine the final list of groundwater COCs requiring action:

- Two pesticides (alpha-BHC and dieldrin) were eliminated as COCs requiring action. Alpha-BHC is an isomer of Lindane but has no MCL. Since it will be treated concomitantly with Lindane no specific action goal has been determined for alpha-BHC. Dieldrin is likely related to historical Basewide pesticide use and is not a site-related contaminant.
- Five metals (antimony, arsenic, beryllium, cadmium, and manganese) were eliminated as COCs requiring action. The first four metals listed were only detected sporadically, often below MCLs. The ubiquitous presence of manganese appears to be related to aquifer chemistry and is not a waste contaminant.
- Three chemicals (1,2-DCA at WP21; cis-1,2-DCE at WP31, OT48, and OT28, and vinyl chloride at WP21, WP31, ST34, and OT28) were added as COCs because they are expected breakdown products of other COCs present at these sites. Although these three breakdown products were not identified as COCs during the field investigation or risk assessment, they are added to the final list here because they are likely to be observed during monitoring of the remedial actions.

With the above-listed additions and deletions, the final list of COCs requiring action at each site and Area 6 are:

GROUNDWATER	
WP21	1,1,1-TCA, 1,1-DCE, 1,2-DCA, cis-1,2-DCE, PCE, TCE, vinyl chloride, Lindane
WP31	Benzene, cis-1,2-DCE, TCE, vinyl chloride
ST34	Benzene, 1,2-DCA, cis-1,2-DCE, PCE, TCE, vinyl chloride, Lindane
OT41/Bldg. 719	cis-1,2-DCE, PCE, TCE, vinyl chloride
OT48	Benzene, cis-1,2-DCE, TCE, vinyl chloride
SS59	COCs for this site are included under Area 6
OT28	cis-1,2-DCE, carbon tetrachloride, TCE, vinyl chloride
Area 6	Benzene, 1,1,1-TCA, 1,1-DCE, 1,2-DCA, cis-1,2-DCE, carbon tetrachloride, PCE, TCE, vinyl chloride, Lindane
SOIL	
SS59	DDD, DDT

During the review, an updated human health risk evaluation was performed by EPA. USEPA may differ with the Air Force on the exact HIs and cancer risks involved, due to differences in exposure and toxicity factors, but was able to confirm the overall conclusions that the risk for workers exposed to sediment and surface water from the various sites would be acceptable. Construction or industrial workers, exposed to groundwater at Sites WP21, ST34, OT41/Bldg. 719, and Area 6 might be exposed to an unacceptable risk. Construction or industrial workers, exposed to groundwater at Sites WP31, OT48, and OT28 should not be exposed to an unacceptable risk.

For the residential exposure scenario, the EPA calculated potentially unacceptable cancer risks (LECR much greater than 1 x 10-4) from the solvents in the groundwater at all the sites and potentially unacceptable non-cancer risks (HIs greater than 1) from the groundwater at each site.

2.6.2 Summary of Vapor Intrusion Risks

Human health risks associated with the vapor intrusion pathway were evaluated separately from the Basewide RI risk assessment of other media. The ATSDR evaluated risks from vapor intrusion in the Base residential area during their public health assessment of DAFB in 2003 (ATSDR, 2003).

The ATSDR applied EPA's Johnson and Ettinger (1991) model to estimate contaminant concentrations in indoor air of the residential buildings overlying the Area 6 plume. The maximum concentrations of 1,2-DCE, PCE, TCE, and vinyl chloride detected in the groundwater plume below the Base housing area were used in the model. The resulting modeled air concentrations were compared to health guidance levels such as ATSDR's inhalation minimal risk levels (MRLs) and other toxicologic literature on these VOCs (summarized in Table 7). This analysis concluded that the concentrations of contaminants in groundwater are much lower than the levels at which adverse health effects would be expected. Uncertainty in the analysis was minimized by using a model that is very protective of human health; by using the maximum contaminant levels in groundwater; and by assuming a long-term residential exposure duration which is generally much longer than for typical military families.

Table 7. ATSDR Summary Results, Base Housing

VOC	Maximum Groundwater Concentration (ppb)	Model Indoor Air Concentration		Inhalation MRL (ppb)	LOAEL (ppb)
		µg/m^3	ppb		
TCE	3,700	74.1	13.8	100	50,000
1,2-DCE	7,500	142.0	35.1	200 *(trans)*	200,000 *(trans)*
PCE	300	8.8	1.3	40	15,000
Vinyl Chloride	280	34	12.7	30	10,000

µg/m^3 – micrograms per cubic meter

ppb – parts per billion

LOAEL – lowest observed adverse effect level

trans – the value shown is for the trans isomer of 1,2-DCE

Sources: ATSDR 1997a, b, c, d; EPA 2003b.

ATSDR, 1997a. Toxicological Profile for Trichloroethylene. Atlanta, GA: Agency for Toxic Substances and Disease Registry. September 1997.

ATSDR, 1997b. Toxicological Profile for 1,2-Dichloroethylene. Atlanta, GA: Agency for Toxic Substances and Disease Registry. September 1997.

ATSDR, 1997c. Toxicological Profile for Tetrachloroethylene. Atlanta, GA: Agency for Toxic Substances and Disease Registry. September 1997.

ATSDR, 1997d. Toxicological Profile for Vinyl Chloride. Atlanta, GA: Agency for Toxic Substances and Disease Registry. September 1997.

USEPA, 2003a. Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings. Available at http://epa.gov.superfund/programs/risk/airmodels. Last updated April 7, 2003.

USEPA, 2003b. Integrated Risk Information System. Available at http://www.epa.gov.iris/.

The Air Force will re-evaluate the vapor intrusion pathway during the groundwater remedial action phase for the Area 6 sites.

2.6.3 Summary of Ecological Risk Assessment

A Basewide ERA was performed as part of the RI and documented in a separate ERA report (USACE, 2000). This assessment is different from the human health risk assessment since it used a Base-wide rather than a site-by-site approach in the evaluation of potential risks. The Basewide approach allows assessment of the cumulative effects of multiple sites on the Base ecology and more reasonably accounts for such factors as foraging range. This assessment, like that for human health, is a complex, multi-step process of comparing data to various benchmarks, and then calculating numerical estimates of risk.

All RI surface water, sediment, surface soil, and groundwater analytical data from all sites were compiled and compared to benchmarks in a tiered approach to evaluate the potential risk. The ERA procedures (a three-tiered process) are outlined below.

2.6.3.1 Tier I: Problem Formulation/Scoping Assessment

The scoping assessment includes 1) characterization of the nature and quality of the habitat and ecological resources on and around the Base; 2) identification of COPCs and receptors of concern (ROCs), and 3) identification of potentially complete exposure pathways. Non-chemical stressors are also identified. The scoping assessment concludes with the elimination of COPCs that do not come in contact with, and thus cannot cause risk to, ROCs.

2.6.3.2 Tier II: Analysis

The objective of this phase of analysis is to focus on those COPCs that are most likely to cause adverse effects (e.g., reproduction problems) in the ROCs. The analysis uses a multi-stage process that compares the list of COPCs developed in Tier I above (i.e., those that have potentially complete exposure pathways) to toxicity screening values (TSVs) using increasingly more realistic assumptions.

2.6.3.3 Tier III: Risk Characterization

For several reasons, COPC concentrations exceeding screening benchmarks may not, in fact, present unacceptable ecological risks. For example, an organism may only be present for short periods in an elevated risk area, which may over-value its significance. If risk is predicted under conservative default assumptions such as 100 percent bioavailability or 100 percent area use factors, more appropriate assumptions are made in an iterative fashion until a more ecologically realistic exposure scenario is produced. This first phase is the Screening Level ERA (SLERA). The SLERA concludes with decisions about the locations and degrees of risk to generic ROCs under reasonable worst-case exposure scenarios. The concentrations used in this part of the assessment are the maximum detected values or the 95 percent UCLs.

The baseline ERA is performed next and synthesizes both toxicological data as well as the ecological data for the site-specific ROCs. Site-specific ROCs such as the kingfisher or shrew were selected based on several factors including how well the ROC represents a specific habitat and its exposure sensitivity. Accumulation of contaminants in the food chain are also taken into account. It may require more than one iteration, depending on the complexity of the site. Carefully identified site and scientific information from peer-reviewed literature are used to reduce uncertainties associated with the conservative assumptions about toxicity and exposure used in the SLERA. Additional iterations are used to reduce uncertainty in the variables used in the evaluation.

The concentrations used in this stage of the assessment may be derived from statistical UCLs, means, or medians, depending on the species-specific foraging habits. If the

estimated concentrations are below species-specific toxicity benchmarks (toxicity reference values [TRVs]), then associated COPC-pathway combinations are concluded to present no unacceptable ecological risk. They are then dropped from further consideration. Any contaminants remaining at this stage are ecological COCs.

2.6.3.4 ERA Results

Surface Water. No unacceptable risk to native fish was calculated for any of the COPCs in surface waters at DAFB. This prediction was validated in bioassay studies that were conducted in the Fall of 1991 on organisms collected at DAFB.

No risk of adverse reproductive effects was calculated for the belted kingfisher (a North American bird) from any of the COPCs that may biomagnify through food chains. This prediction was partially validated as no pesticides or polychlorinated biphenyls (PCBs) were found in fish collected from Pipe Elm Branch, Morgan Branch, or the St. Jones River tributary that runs through the DAFB golf course. Since the kingfisher has a higher exposure rate than the raccoon, mallard, or muskrat, and reproductive endpoints were used to establish TRVs for these species, there is no risk of reproductive ill effects in any of these potential ROCs.

The ERA concluded that no action is necessary to address ecological risks for the surface water medium at DAFB because no unacceptable risk was found for any ROC exposed to any surface water COPC.

Sediment. A low degree of risk was calculated for benthic invertebrates (e.g., worms) exposed to the 95 percent UCL for sediment zinc concentrations. The highest risk was found in the upstream portion of the North Drainage Ditch (ERP Site SD12), which discharges to Pipe Elm Branch. However, no risk was calculated for benthic invertebrates exposed to the mean zinc concentration, even within Pipe Elm Branch, because the highest zinc concentrations were detected within a small, localized area at the end of a drainage pipe in the SD12 area. No risk to benthic invertebrates was calculated for any other COPC in sediment. This conclusion was validated in bioassay studies conducted in 1991.

A low risk of adverse reproductive effects was calculated for snipe (a bird common to marshes) exposed to the 95 percent UCL for sediment DDD, dichlorodiphenyldichloro-ethylene (DDE), and DDT concentrations. The highest concentrations of DDD, DDE, and DDT were found near a portion of Pipe Elm Branch in the East Management Unit. However, even in this area, no unacceptable risk was calculated for snipes exposed to the mean DDD, DDE, and DDT concentrations. Since the snipe has a higher exposure rate than raccoon, mallard, or muskrat, and reproductive endpoints were used to establish TRVs for these species, there is no risk of reproductive ill effects in these potential ROCs.

The ERA concluded that zinc, DDT, DDD, and DDE in sediment pose some minor, localized risks to the environment. However, ecological risks over an entire drainage

area are minimal. The localized risks at Site SD12 and the Pipe Elm Branch are being addressed in the Proposed Plan and ROD for Site SD12.

Soil. COPCs in soil posed no unacceptable risk to any ROC, and, therefore, the ERA concluded that no action is necessary to address ecological risks from soil at DAFB.

Groundwater. Ecological risks were assessed for groundwater as it discharges to surface streams or flows towards the Base boundaries. No unacceptable risks to ROCs were found, thus no further action is necessary to address ecological risks from groundwater at DAFB.

During the USEPA ecological risk review, it was confirmed that the ERA results and conclusions for soil, surface water and sediments, and groundwater at the sites covered by this ROD were accurate.

2.6.4 Basis for Action

The human health risk assessment for Area 6 and its seven associated sites concluded that:

- Carcinogenic risk from hypothetical future commercial/industrial exposure to groundwater at WP21, ST34, OT41/Bldg. 719, and Area 6 (which includes SS59) exceeds the USEPA risk criterion.

- Groundwater contaminant concentrations at all seven sites and Area 6 exceed federal MCLs. There are residential, industrial, and agricultural users of the Columbia Aquifer within the surrounding community. Because the Columbia Aquifer is a currently used drinking water source, MCL exceedances at all seven sites and the Area 6 plume trigger the need for action.

- Non-carcinogenic risk from hypothetical future commercial/industrial exposure to groundwater at WP21, WP31, ST34, OT41/Bldg. 719, OT48, OT28, and Area 6 (which includes SS59) exceeds the USEPA risk criterion.

Additionally, although no unacceptable human health risks were found for soil at WP21, WP31, ST34, OT41/Bldg. 719, OT48, and Area 6 (which includes SS59), this conclusion was based on the assumption that land use at these six sites will remain industrial, and that the integrity of the asphalt cover at SS59 will be maintained. At OT28, the soil was determined to be suitable for unrestricted exposure and unlimited use based on the residential scenario used for its risk assessment. Therefore, action is required to address groundwater risks at all seven sites and the Area 6 plume, and to ensure the permanence and reliability of the land use assumptions used to assess the sites. It is the USAF's current judgment that the response action selected in this ROD is necessary to protect the

public health or welfare from actual releases of hazardous substances into the environment at WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, and Area 6.

2.7 REMEDIAL ACTION OBJECTIVES (RAOs)

RAOs are medium-specific goals that the selected remedial alternative must achieve to protect human health and the environment. The development of RAOs for the sites in this ROD was documented in the FS for the WMU (USACE, 2005) based on the results of the human health risk assessment. The RAOs developed for soil and groundwater contamination at the seven Area 6 sites are as follows:

(a) Reduce concentrations of the specified contaminants identified in the Columbia Aquifer near these sites and within Area 6 to the levels shown in Table 8. These quantitative RAOs (also called Preliminary Remediation Goals) are based on the federal drinking water MCLs established under the Safe Drinking Water Act.

(b) Prevent exposure to groundwater from the Columbia Aquifer near these sites and Area 6 until such time as cleanup levels (shown in Table 8) for the contaminants in the aquifer have been obtained and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use.

Table 8. Quantitative Groundwater RAOs

Contaminant	WP21	WP31	ST34	OT41/ Bldg. 719	OT48	SS59	OT28	Area 6	RAO* (µg/L)
Benzene		X	X		X			X	5
1,1,1-TCA	X							X	200
1,1-DCE	X							X	7
1,2-DCA	●		X					X	5
cis-1,2-DCE	X	●	X	X	●		●	X	70
PCE	X		X	X				X	5
TCE	X	X	X	X	X		X	X	5
Carbon tetrachloride							X	X	5
Vinyl chloride	●	●	●	X	X		●	X	2
Lindane	X		X			X		X	0.2

X = COC present at this site.
● Potential COC due to the breakdown of other COCs.
*RAO is the Federal MCL

(c) Maintain the asphalt cover at SS59 to prevent human exposure to residual pesticides in surface soil, and to reduce infiltration of surface water that may leach pesticides into groundwater, until concentrations of hazardous substances at the site are shown to be at levels allowing for unrestricted exposure and unlimited use.

LUC Objectives: The Air Force has identified the following LUC performance objectives:

- Prohibit the development and use of Sites WP21, WP31, ST34, OT41/Bldg 719, OT48, and SS59 for residential housing, elementary or secondary schools, day care centers, and playgrounds until concentrations of hazardous substances at the site are at levels allowing for unrestricted exposure and unlimited use.
- Prohibit the use of on-Base groundwater from the Columbia Aquifer (first shallow, unconfined aquifer) within the West Management Unit until cleanup levels are met and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use.
- Prohibit digging and other ground-disturbing activities at all of the sites that are inconsistent with the objectives listed above. A more complete discussion of the review process is provided in Section 2.8.1.11.
- Maintain the integrity of any current and future remedial or monitoring system at these sites.

2.8 DESCRIPTION OF ALTERNATIVES

The remedial action alternatives selection process evaluates and compares remedial alternatives. Remedial action technologies are identified and screened for possible use using the following process:

- Identify ARARs for the sites. ARARs for the Area 6 sites are tabulated in Attachment 2.
- Develop RAOs for the COCs in all affected media (Section 2.7).
- Identify general response actions for each environmental medium requiring remediation to satisfy the RAOs.
- Identify site-specific remedial technologies that are potentially applicable to each general response action, followed by screening of these technologies based on the criteria of implementability, effectiveness, and cost. The objective is to identify those technologies best suited for further consideration in developing remedial alternatives for the sites/areas. Technologies found to be inapplicable on the basis of waste characteristics and site conditions or incapable of meeting the RAOs are eliminated from further consideration. The remaining candidate technologies that pass the screening process are combined into remedial action alternatives. The alternatives for Area 6 sites are described below.

2.8.1 Description of Remedy Components

The Air Force evaluated potential remedial alternatives to address groundwater contamination at Area 6 and the seven associated sites. The alternatives evaluated in the FS for the WMU are:

- A1 – No Action
- A2 – Natural Attenuation
- A3 – Chemical Oxidation[1]
- A4 – Groundwater Recirculation Wells (GRWs)
- A5 – Permeable Reactive Barriers (PRBs)
- A6 – Groundwater Extraction and Air Stripping (also known as Pump and Treat)
- A7 – Injection/Diffusion Accelerated Anaerobic Biodegradation (AAB)
- A8 – AAB and Natural Attenuation

All of these alternatives listed above include groundwater monitoring, continued operation of the existing AAB recirculation system at OT41/Bldg. 719, maintenance of the asphalt cover at SS59, LUCs, and evaluation of vapor intrusion as common components of each active remedy. Each of these individual alternatives is described below, followed by discussions of the common components.

2.8.1.1 A1 – No Action

The no action alternative involves no remedial actions. No efforts would be undertaken to contain, remove, treat, or monitor the Area 6 contaminant plume. Access to the sites would not be restricted. No LUCs would be undertaken. The no action alternative is required by Federal regulation to be evaluated so as to provide a reference point for comparing other remedial alternatives. Under the "No Action" alternative, the contaminants would continue to degrade; however, the rate of degradation would remain unmeasured. This alternative would not rely on LUCs to prevent or minimize the risk of unacceptable exposure to human receptors.

2.8.1.2 A2 – Natural Attenuation

This alternative relies on naturally occurring biological and physical processes (e.g., biodegradation, dispersion, dilution) to reduce chlorinated solvent and fuel contaminant concentrations in groundwater within Area 6. Under this alternative, source areas (areas of highest groundwater contaminant levels) and the distal areas of the plume would be addressed by natural attenuation. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of the process. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11. O&M requirements for this alternative are minimal, and would primarily involve monitoring well maintenance activities.

A detailed natural attenuation study has already been conducted for the Area 6 plume by the RTDF as described in Section 2.4.5 (RTDF, 1997). The general finding from the RTDF study is that natural attenuation is resulting in the reduction and transformation of

[1] The chemical oxidation alternative was not evaluated for the Area 6 sites, but it is listed here to maintain continuity with the numbering of the alternatives in the FS for the WMU (USACE, 2005). The FS evaluated the chemical oxidation alternative for other sites that are not included in this ROD. For purposes of this ROD, the "A3 – Chemical Oxidation" alternative will not be mentioned further, and where the text refers to "all alternatives", it means the seven other alternatives listed here, excluding alternative A3.

chlorinated solvents within the Area 6 plume. Highly chlorinated contaminants, such as PCE, TCE, and Lindane, biodegrade in the upgradient portion of the Area 6 plume under naturally anaerobic (low-oxygen) conditions. More aerobic (high-oxygen) conditions exist in the downgradient portion of the Area 6 plume where the lesser chlorinated contaminants, such as cis-1,2-DCE and vinyl chloride, complete their degradation process.

2.8.1.3 A3 – In Situ Chemical Oxidation

This alternative was not evaluated for the Area 6 sites but is listed in this ROD to maintain continuity with the numbering of alternatives in the FS for the WMU. See footnote 1 (page II-49).

2.8.1.4 A4 – Groundwater Recirculation Wells (GRWs) with In-Well Stripping

This alternative includes the *in situ* treatment of groundwater using groundwater recirculation wells installed in defined source areas, or at site boundaries in cases where defined sources do not exist. The process is a type of air sparging that consists of a specially adapted groundwater well that is dual-screened at the base of the well and across the water table. The wells circulate water within the aquifer while injecting air. The air strips organic contaminants from the water which are flushed into the soil above the water table. The contaminants are then recovered and treated using an above-ground vacuum pump and off-gas treatment system (activated carbon). The stripped groundwater is discharged from the well and re-enters the aquifer. O&M requirements for this alternative are in the high range relative to other alternatives, and would include treatment system sampling and analysis, air emissions monitoring, miscellaneous repairs and replacement of worn parts, well maintenance, checking carbon, replacement of carbon canisters, and proper disposal of spent carbon.

This technology would be used to treat the two target areas (Target Area 1,2,3 and Target Area 6, Figure 2). It would be used as a boundary control strategy at OT28 where there is no distinct contaminant source area, but rather a small area of relatively low level contamination. The untreated portions of the plumes would be allowed to naturally attenuate. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of this process. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11.

2.8.1.5 A5 – Permeable Reactive Barriers (PRBs)

This alternative involves the emplacement of a reactive material in the path of groundwater flow in order to enhance the degradation of contamination. The technology involves the installation of an impermeable barrier in the aquifer interspersed with permeable sections where the reactive material is emplaced. The impermeable sections of the barrier funnel the contaminated groundwater through the permeable reactive material. The reactive material (usually zero-valent iron) abiotically degrades chlorinated VOCs. This technology is not effective for fuel contaminants. Operation and

maintenance requirements for this technology are minimal and include periodic barrier wall inspections and servicing.

This technology is used as a boundary control and not a source area treatment. It would be applied at the downgradient end of the two target areas within the Area 6 plume near the Base boundary at U.S. Route 113. Contaminants in the untreated portions of Area 6 would be allowed to naturally attenuate. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of this alternative. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11.

2.8.1.6 A6 – Groundwater Extraction and Air Stripping (Pump and Treat)

Under this alternative, vertical wells are installed in the aquifer and pumps are installed in the wells to extract contaminated groundwater. The extracted groundwater would be pumped to an above-ground treatment system where it would undergo metals pre-treatment before being sent through an air stripping unit to remove VOCs. The metals pre-treatment is required to remove naturally occurring metals such as iron and manganese which can foul air stripping equipment. Because air stripping will not remove the contaminant Lindane from water, the groundwater that discharges from the air stripper would be further treated using granulated activated carbon (GAC) to remove Lindane. The treated groundwater effluent would be tested for VOCs and Lindane to verify regulatory compliance prior to discharge. O&M activities for this technology are in the high range relative to other alternatives, and include effluent sampling and monitoring, maintenance (clean stripper, check carbon), periodic redevelopment of wells, miscellaneous repairs and replacement of worn parts, replacement of carbon canisters, and proper disposal of spent carbon.

This alternative would be applied as a source control strategy at the two target areas. It would be applied as a boundary control strategy at OT28 where there is no distinct contaminant source area, but rather a small area of low level contamination. For the target areas, treated groundwater would be discharged to a nearby sub-drain that feeds into a stormwater sewer main, and ultimately discharges to the St. Jones River. For OT28, treated groundwater would be discharged to the St. Jones River. The portions of the plume not treated by the groundwater extraction wells would be allowed to naturally attenuate. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of this alternative. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11.

2.8.1.7 A7 - Injection/Diffusion Accelerated Anaerobic Biodegradation (AAB)

AAB is an *in situ* innovative technology used to stimulate natural biodegradation processes and remediate organic contamination (including chlorinated VOCs and Lindane) in groundwater. The AAB application consists of introducing organic substrates and nutrients into the aquifer to stimulate the growth of native microorganisms, creating an environment where the biodegradation processes occur more rapidly than in the natural system. Within Area 6, introduction of an organic (carbon-containing)

substrate and nutrients would enhance the anaerobic environment, stimulate the growth of halorespiring anaerobes, and thereby accelerate the rate of reductive chlorination of the contaminants.

The injection/diffusion method of applying the AAB technology uses natural groundwater flow to disperse the injected substrate and nutrient materials into the contaminated aquifer. These materials are injected into the aquifer either through installed groundwater wells or by direct emplacement using a direct push rig or other insertion device. Once injected, the materials flow out into the aquifer via natural advection and dispersion. Multiple or periodic re-injections of the substrate materials may be required depending on the substrate used and the geochemical conditions at the site. O&M activities for this alternative could include redevelopment of wells if needed, but primarily involve multiple re-injections of substrate materials after the initial treatment.

This alternative would be used as a source area treatment at the two target areas. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of this alternative. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11.

2.8.1.8 A8 – AAB and Natural Attenuation with Monitoring

This alternative includes a combination of the AAB and natural attenuation technologies described in paragraphs 2.8.1.2 and 2.8.1.7. AAB would be used to treat the two target areas within the Area 6 plume, which encompass Sites WP21, ST34, and SS59 (Figure 2). Natural attenuation would apply to the portion of the Area 6 plume not treated by AAB, specifically OT48, WP31, and OT28. See Section 2.8.1.9 for a discussion of the AAB remedy already in place at OT41/Bldg. 719. Periodic groundwater monitoring would be conducted to evaluate the effectiveness of this alternative. LUCs would be implemented to control human exposure to contaminants at the sites as described in Section 2.8.1.11. O&M activities would primarily involve monitoring well maintenance and re-injection of substrate within the AAB treatment areas.

2.8.1.9 AAB Recirculation at OT41/Bldg. 719

In 2000-2001, an AAB system was installed at OT41/Bldg. 719 to treat the single largest source of chlorinated solvents in groundwater within the Area 6 plume (a potential principal threat waste). The system comprises four extraction wells, 12 injection wells (seven of which were angled to reach underneath Building 719), 20 monitoring wells, and a process building. Contaminated groundwater is extracted on the downgradient side of Building 719, pumped through underground pipes into the process building where amendments are added, and then reinjected into the ground on the upgradient side of Building 719. Sodium lactate (an organic carbon source) and dibasic ammonium phosphate (nutrients) are the amendments being used to stimulate the indigenous microbial organisms that reductively dechlorinate groundwater contaminants. The system is operated and maintained on a weekly schedule with periodic sampling to

monitor system performance. Tolcide PS200, an anaerobic biocide, was approved by USEPA to control injection well biofouling and is used occasionally to help maintain pumping rates.

Within the first year of operating the AAB system, approximately 8 million gallons of groundwater circulated through the system and the anaerobic environment underneath Building 719 expanded and became more reductive. Chemical evidence of complete biodegradation of the chlorinated contaminants continues to be observed.

Natural groundwater fluctuations bring the groundwater table elevation up very close to the building foundation during peak rainy periods. Analytical data show that contaminants in soil underneath Building 719 are being flushed into the groundwater where they are captured and treated by the AAB system. The sodium lactate acts as a surfactant to mobilize contaminants out of the soil. Once mobilized into the treatment zone, data show that the contaminants, primarily TCE, are quickly biodegraded. Thus, any remaining source materials in soil are being treated by this system, as well as the groundwater contaminants.

The continued operation of the OT41/Bldg. 719 system is a component of all of the action alternatives. Upon its signing, this ROD will supersede the 1995 interim ROD for the AAB recirculation remedy.

2.8.1.10 Soil Removal and Cover at SS59

In accordance with a 1995 ROD (DAFB, 1995d) and a 1997 EECA (HAZWRAP, 1997b), a soil removal and capping action was conducted at SS59. Excavation fieldwork commenced on October 23, 1998 and was completed by mid December 1998. Additional soil samples were collected in March 1999 just prior to placement of the asphalt cover. The major components of the work are listed below:

- Four ‘hot-spots’ (areas of elevated pesticide contamination relative to the rest of the site) were located by a licensed surveyor.
- Approximately 147 tons of contaminated soil from the four hot spots were excavated and sent off-site to a permitted incinerator facility.
- Twenty confirmation soil samples were collected and analyzed for pesticides. Results indicated that some pesticides were still present at three of the four ‘hot-spots.’
- The excavation was backfilled with clean soil and graded.
- Additional soil samples were collected, to determine the vertical extent of the residual pesticide contamination. Results indicated that residual contamination was in the shallow soils and did not extend to the water table.
- In April 1999, the asphalt capping system was installed over an area of approximately 220 ft by 124 ft, including the three hot-spot areas where pesticides were still present at levels above screening criteria. The asphalt cap was installed

as part of a USEPA SITE Program project proposed by Wilder Construction. A portion of the asphalt cap includes Wilder Construction's Modified Asphalt Technology for Waste Containment (MATCON) which is a proprietary, modified asphalt that is designed to have very low permeability.

Industrial soil screening criteria for pesticides were used as guidelines during the SS59 soil remediation project. Because residual pesticide contamination remains under the asphalt cap at levels exceeding industrial soil screening criteria, ensuring the integrity of the SS59 asphalt cover is a component of all the action alternatives to prevent leaching of, and prevent human exposure to, residual pesticide contamination in the shallow soil.

2.8.1.11 LUCs

The Air Force has identified the following LUC performance objectives:

- Prohibit the development and use of Sites WP21, WP31, ST34, OT41/Bldg 719, OT48, and SS59 for residential housing, elementary or secondary schools, day care centers, and playgrounds until concentrations of hazardous substances at the site are at levels allowing for unrestricted exposure and unlimited use.
- Prohibit the use of on-Base groundwater from the Columbia Aquifer (first shallow, unconfined aquifer) within the West Management Unit until cleanup levels are met and risks from groundwater use are shown to be reduced to levels that allow for unrestricted exposure and unlimited use.
- Prohibit digging and other ground-disturbing activities at all of the sites that are inconsistent with the objectives listed above.
- Maintain the integrity of any current and future remedial or monitoring system at these sites.

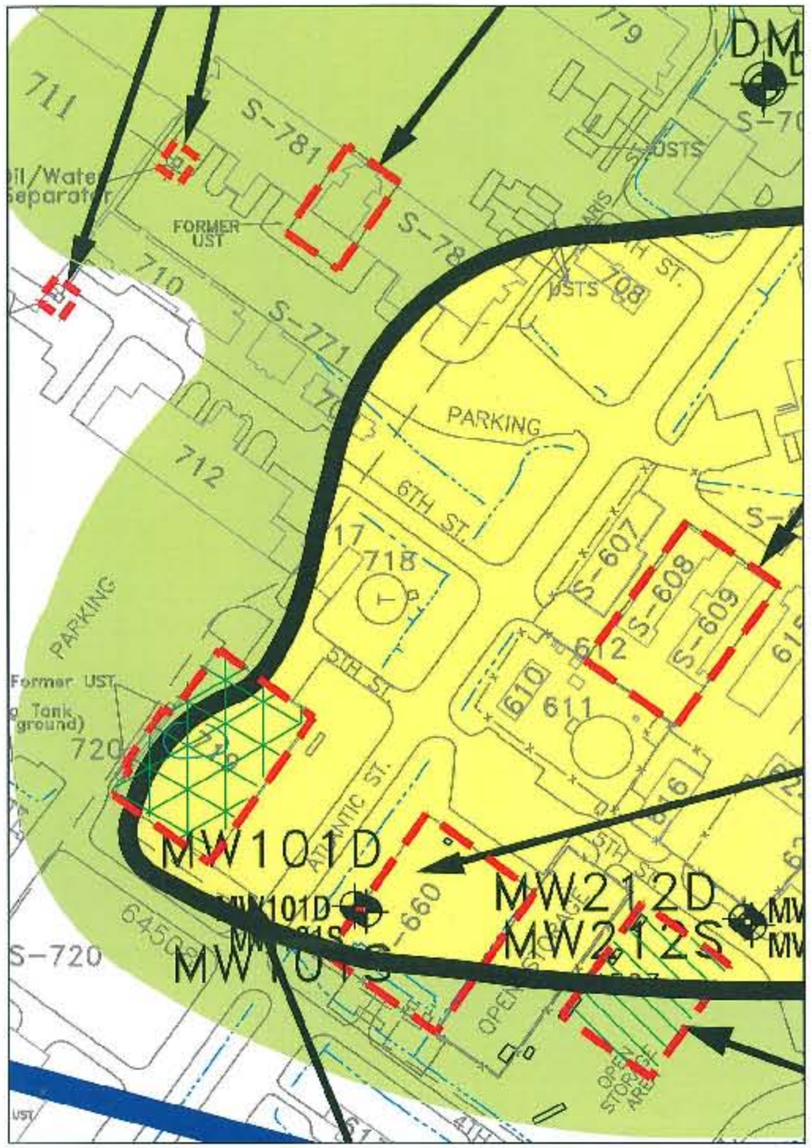
LUCs are a component of each of the remedial alternatives described above except for Alternative A1 – the No Action alternative. LUC provisions as they apply to Area 6 and the seven sites in this ROD include the following:

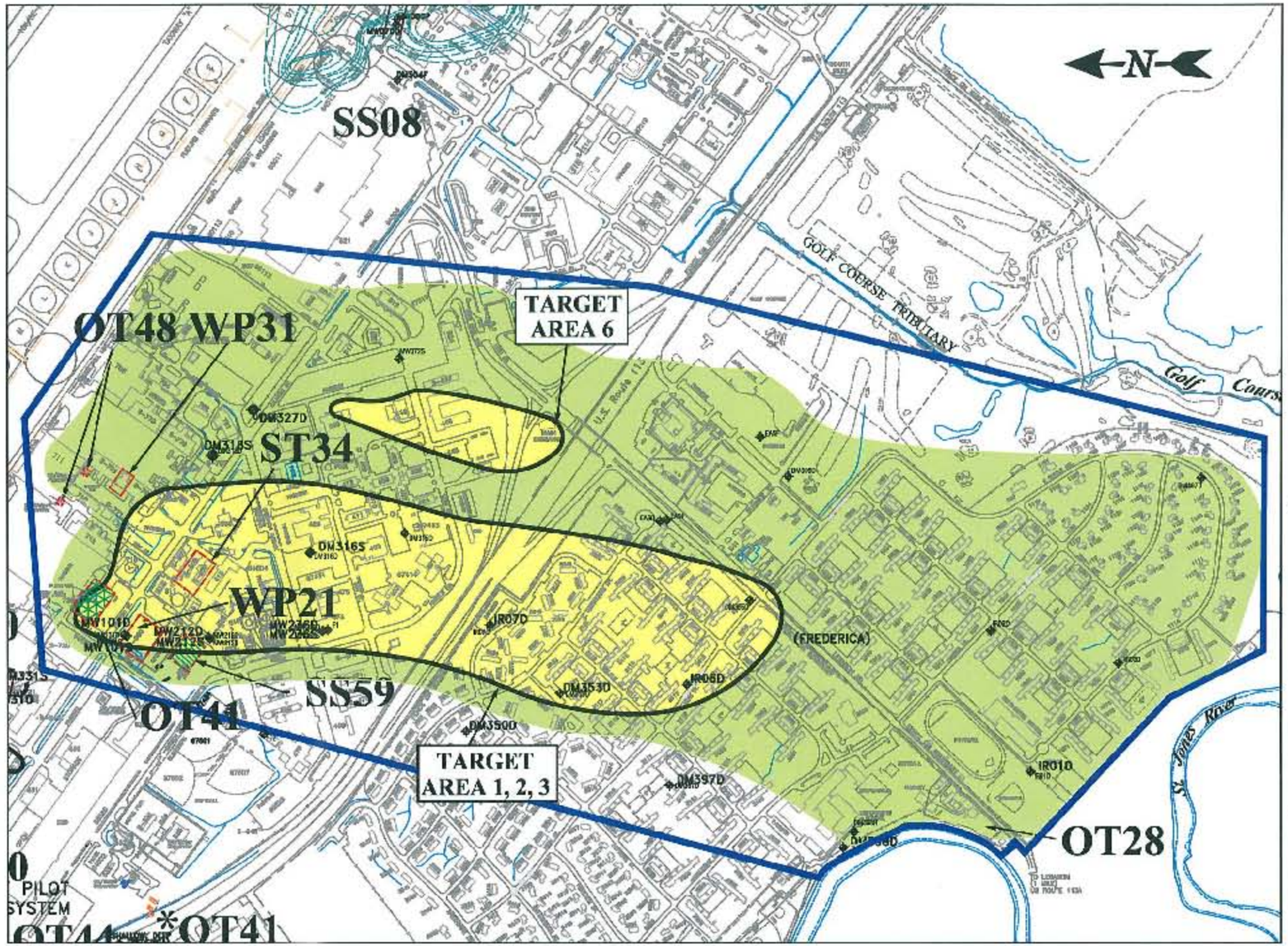
- The Air Force is responsible for and will implement, maintain, monitor, review, report on, and enforce LUCs at Area 6 and its seven associated sites in accordance with CERCLA and the NCP to ensure protection of human health and the environment until the concentration of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted exposure and unlimited use.
- Land use at WP21, WP31, ST34, OT41/Bldg. 719, OT48, and SS59 is restricted to industrial/commercial/non-residential purposes. Residential uses, housing, schools, day-care centers, and recreational areas are prohibited until concentrations of hazardous substances at these sites are at levels allowing for unrestricted exposure and unlimited use. On-site use of groundwater from the Columbia Aquifer is prohibited at all seven sites (including OT28) and Area 6 as

a whole until cleanup levels (shown in Section 2.7 Table 8) have been obtained and risks from groundwater use are shown to be reduced to allow for unrestricted exposure and unlimited use. Specific controls that will be used to implement these land use restrictions and prohibitions are:

- DAFB has a system for comprehensive land use planning that is currently established by Air Force Instruction (AFI) 32-7062, as further implemented in Air Force Pamphlet 32-1010. The Base General Plan provides pertinent information used in planning and decision-making regarding permissible current and future land and groundwater uses and activities on DAFB. DAFB will upon ROD execution promptly revise the Base General Plan to include all land use restrictions and controls identified by this ROD, to include information and maps related to their location and duration, and listing the 436 CEVR as the point of contact for such restrictions and controls. DAFB shall provide USEPA and DNREC with draft copies of the section of the Base General Plan pertaining to LUCs for review at least 30 days prior to implementation. DAFB shall ensure that these or equivalent systems and procedures are used for the duration of the remedies specified in this ROD. DAFB shall provide USEPA and DNREC with 30 days notice before initiating any changes to the Base General Plan that relate to these site restrictions and controls.
- The Air Force has administrative processes and procedures that require approval for all projects involving construction or digging/subsurface soil disturbance, currently set forth in AFI 32-1001, Operations Management, and AFI 32-1021, Planning and Programming of Facility Construction Projects (also known as the base digging permit process). These instructions require coordination and approval by base environmental personnel for projects located in or near ERP sites, including sites that have LUCs. DAFB will ensure these or equivalent processes and procedures remain in place and are complied with for all proposed construction, digging and subsurface soil disturbing activities at WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and OT28. DAFB shall provide USEPA and DNREC with 30 days notice before initiating any changes to the "digging permit process" as it relates to these site restrictions and controls.
- The Delaware DNREC has established a GMZ around DAFB and adjacent properties as documented in the March 2003 DNREC *Memorandum of Agreement (MOA) for Dover Air Force Base and Environs*. The GMZ is an internal DNREC mechanism whereby DNREC's Division of Water Resources, Well Permitting Section, ensures that no groundwater well permits are issued for use of the unconfined aquifer on-Base, or at specified off-Base areas around the perimeter of DAFB, without prior written approval from the DNREC Site Investigation and Restoration Branch. Areas restricted for well permitting under the GMZ include the off-Base area directly downgradient of Area 6. Maps depicting the restricted areas are included in DNREC's March 2003 MOA.

- The Air Force is responsible for all land use and activity restrictions and controls identified in this ROD with the exception of the GMZ which restricts well installation into portions of the unconfined aquifer on DAFB and surrounding areas as described above. The Delaware DNREC developed the GMZ and is responsible for any changes to it, and for implementing, overseeing, and enforcing the GMZ.
- All of the use and activity restrictions and controls set forth in this ROD shall remain in place until concentrations of hazardous substances at Area 6 and associated sites are shown to be at levels allowing for unrestricted exposure and unlimited use. For OT28, soil is already suitable for unlimited use.
- Figure 3 is a map showing the on-Base area at Area 6 affected by land use restrictions for both soil and groundwater. For soil, LUCs will be implemented with a 10-foot setback from the edge of Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, and Area 6. For groundwater, LUCs will be applied to the entire plume area as shown in Figure 3. Maps showing this area and the areas affected by the DNREC GMZ will be included in the Base General Plan.
- DAFB personnel shall annually monitor and visually inspect all land use restrictions and controls specified in this ROD to evaluate the status of the LUCs, determine the effectiveness of and compliance with these restrictions and controls, and evaluate how many LUC deficiencies or inconsistent uses have been addressed. The inspections and monitoring will include determining any violations of the LUCs, as well as indications of tampering, trespass, and incompatible use. This item does not apply to OT28 soil.
- An annual report of monitoring and inspection will be developed by DAFB and submitted to USEPA and DNREC, starting one year from the date of execution of this ROD. The monitoring report will not be subject to approval and/or revision by the USEPA or DNREC. The report will briefly describe the measures by which the Base monitored and inspected the land use restrictions and controls specified in the ROD, state any violations or deficiencies and measures to address them, and assess whether the restrictions and controls have been complied with and whether Base implementing procedures are effective. The annual evaluation will address whether the owners and state and local agencies were notified of the use restrictions and controls affecting the property, and whether use of the property has conformed with such restrictions and controls. This report shall also be filed in the Administrative Record. These annual monitoring reports will be used in preparation of the Five Year Review to evaluate the effectiveness of the remedy.





LEGEND:

- Target Areas
- Monitoring Well
- Area 6 Plume
- Accelerated Biodegradation
- Natural Attenuation
- SS59 Cover
- Building 719 Injection/ Recirculation AAB System
- Base Boundary
- LUCs for soil, Set back distance 10 feet
- On-Base LUCs for groundwater. Off-Base LUC boundary is defined in the DNREC GMZ

Note: Final locations of new wells and selection of the monitoring network will be presented in the remedial action work plan.

400 0 400 800
SCALE IN FEET

FIGURE 3
LAYOUT OF ALTERNATIVE A8, AREA 6

URS

(back of figure 3)

- Any activity that is inconsistent with the land use restrictions, or any other action that may interfere with the effectiveness of the restrictions will be addressed by DAFB as soon as practicable, but in no case will the process be initiated later than ten (10) days after DAFB becomes aware of the breach.
- DAFB shall provide prompt notice to USEPA and DNREC if it discovers any activity that violates, is inconsistent with, or may interfere with the land use restrictions and controls specified in this ROD. The notice shall include any corrective measures taken or planned to address the violation, failure, or deficiency. Verbal notice shall occur within three (3) calendar days of discovery, to be followed by written notice within ten (10) calendar days.
- The Air Force shall not modify or terminate LUCs, implementation actions, or modify land use at the sites specified in this ROD without prior approval by EPA and the State. The Air Force shall seek prior concurrence before any anticipated action that may disrupt the effectiveness of the LUCs or any action that may alter or negate the need for LUCs.
- The Air Force shall provide notice to USEPA and DNREC, consistent with the requirements of CERCLA § 120(h), at least six (6) months prior to any anticipated transfer or lease of property that includes Area 6 to a private, local, or state entity, and provide such regulators the opportunity to discuss with the Air Force appropriate provisions in the transfer or lease documents to maintain the Area 6 land use restrictions and controls. If notice within six months is not possible, the Air Force shall do so as soon as possible, but not later than sixty (60) days prior to such transfer or lease. The Air Force further agrees to provide similar notice as to federal to federal transfer of property accountability and administrative control of Area 6. The Air Force shall provide a copy of an executed deed or transfer assembly to EPA and DNREC.
- DAFB shall notify USEPA and DNREC at least 45 days in advance of any proposed land use changes that are inconsistent with the land use control objectives or the selected remedy in this ROD.
- DAFB will maintain the integrity of any current and future remedial or monitoring system.

2.8.2 Common Elements and Distinguishing Features of Each Alternative

All of the alternatives, except A1 – No Action, are capable of meeting the RAOs discussed in Section 2.7, and will comply with ARARs. However, several of the alternatives must comply with additional action-specific or chemical-specific ARARs due to the nature of the treatment. Alternatives A4 (GRWs) and A6 (Pump and Treat) require compliance with the substantive requirements of the Delaware Regulations Governing Control of Air Pollution due to air emissions associated with the above-ground treatment systems. Alternative A6 also requires compliance with Clean Water Act pollutant discharge requirements due to the discharge of treated groundwater to surface water. Alternatives A7 (AAB), and A8 (AAB with Natural Attenuation) require compliance

with the substantive requirements of the Delaware Regulations Governing Underground Injection Control due to the injection of substrate materials into the aquifer.

All of the alternatives except A1 are considered reliable in the long term. Only two of the alternatives, A4 and A6, would have residues requiring off-site disposal. These residues are in the form of spent activated carbon for both alternatives, and in the case of A6, small volumes of sludge associated with metals pre-treatment.

Estimated time to design and construct is moderate for all of the alternatives (excluding A1 which requires none), with alternatives A2, A7, and A8 requiring more limited design and less time to implement than alternatives A4, A5, and A6. Of the seven alternatives evaluated for Area 6, alternative A6 is a presumptive remedy, and A4, A5, A7, and A8 involve the use of innovative technologies.

Comparisons of time to reach RAOs and costs for each alternative are included in Sections 2.9.5 and 2.9.7, respectively.

2.8.3 Expected Outcomes of Each Alternative

Given that alternative A1 is no action, by definition there would be no reduction in risk, no restrictions on use of land or groundwater, and no control over human exposure to contamination.

Alternatives A2 through A8 all include land use restrictions and controls. Under these alternatives, land use at all sites would remain available for industrial use and land use at OT28 would also be unrestricted for residential use.

Alternatives A2 through A8 will all result in the availability of the Columbia Aquifer on-Base for drinking water use. The time to achieve this use varies for each alternative as discussed in Section 2.9.5.

2.9 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

In the FS for the WMU (USACE, 2005), the seven alternatives discussed in Section 2.8 of this ROD were comparatively evaluated to determine the most suitable option capable of achieving the RAOs. The nine standard criteria used in this evaluation are described in Table 9. The first two criteria, Overall Protection of Human Health and the Environment and Compliance with ARARs, are threshold criteria. Any alternative must be both protective and comply with ARARs before it can be considered as a remedy. The next five criteria – Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility, or Volume through Treatment; Short-term Effectiveness; Implementability; and Cost – are balancing criteria. The relative merits and tradeoffs among the alternatives are evaluated with these five criteria. The remaining two criteria, State Agency Acceptance and Community Acceptance, are modifying criteria that are addressed after agency and public comments have been received.

Table 10 summarizes the salient details of the comparative analysis of alternatives. Evaluations of the alternatives against each of the nine criteria are discussed in more detail in the following subsections.

2.9.1 Overall Protection of Human Health and the Environment

This criterion addresses whether each alternative provides adequate protection of human health and the environment, and describes how risks are eliminated, reduced, or controlled, through institutional controls, engineering controls, treatment, or natural attenuation. There are no risks to the environment from the Area 6 sites. Therefore the analysis focuses on protection of human health. All of the alternatives, except the No Action alternative, are protective of human health by reducing or controlling risks from the Area 6 sites through treatment of groundwater contaminants and implementation of LUCs. Each alterative, except the No Action alternative, has a long-term monitoring component that will allow the agencies to document the development and success of the alternative that is selected.

Table 9. Remedy Evaluation Criteria

1	***Overall Protection of Human Health and the Environment*** determines whether an alternative eliminates, reduces, or controls threats to public health and the environment.
2	***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)*** evaluates whether the alternative meets federal and State environmental statutes, regulations, and other requirements that are applicable or relevant and appropriate to the site, or whether a waiver is justified. Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate federal and State requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless such ARARs are waived under CERCLA Section 121(d)(4).
3	***Long-term Effectiveness and Permanence*** considers the ability of an alternative to maintain protection of human health and the environment over time, once cleanup levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.
4	***Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment*** evaluates an alternative's use of treatment to reduce the harmful effects of principal contaminants, their ability to move in the environment, and the amount of contamination present.
5	***Short-term Effectiveness*** considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation and operation until cleanup levels are achieved.
6	***Implementability*** considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services.
7	***Cost*** includes estimated capital and annual O&M costs, as well as present worth cost. Present worth cost is the total cost of an alternative over time in terms of today's dollar value.
8	***State Agency Acceptance*** considers whether the State agrees with or opposes the preferred alternative.
9	***Community Acceptance*** considers whether the local community agrees with or opposes the preferred alternative. Comments received on the Area 6 Proposed Plan are an important indicator of community acceptance and are documented in Part III (Responsiveness Summary) of this ROD.

Table 10. Comparative Analysis of Alternatives

Criterion	A1 No Action	A2 Natural Attenuation	A4 Groundwater Recirculating Wells	A5 Permeable Reactive Barrier	A6 Groundwater Extraction and Air Stripping	A7 Injection/Diffusion AAB	A8 AAB and Natural Attenuation
Overall Protection							
• Human Health Protection	Unknown. No mechanism to prevent exposure or monitor groundwater conditions.	Offers an adequate level of overall protection of human health through existing LUCs on-Base. May not achieve RAOs downgradient of TA 1, 2, 3 because TCE plume has not yet stabilized. Natural attenuation requires relatively more time to achieve the RAOs than do more aggressive treatment technologies.	Offers an adequate level of overall protection of human health through existing LUCs on Base. Treatment of constituents will allow achievement of RAOs downgradient of the GRW barrier systems. Active treatment by the recirculating wells will allow achievement of RAOs within and downgradient of the treatment area. Prevents further offsite migration of compounds. As a barrier technology, GRWs require relatively more time to achieve the RAOs than do more aggressive treatment technologies.	Offers an adequate level of overall protection of human health through the existing LUCs on-Base. PRBs will achieve RAOs at the point of treatment thereby preventing expansion of plume. As a barrier technology, PRBs require relatively more time to achieve RAOs than do more aggressive treatment technologies.	Offers an adequate level of overall protection of human health through the existing LUCs. Active air stripping treatment of constituents will allow achievement of RAOs as demonstrated through groundwater monitoring. Constituent concentrations are likely to be decreased considerably after a relatively short operating period, but are likely to rebound to existing concentrations following cessation of pumping activities.	Offers a good level of overall protection of human health through the existing LUCs. AAB will achieve RAOs. This alternative does not address contamination at OT28. The ability to apply AAB technology over widespread areas accelerates remediation times over most other technologies.	Offers a good level of overall protection of human health through the existing LUCs. The combination of *in situ* bioremediation via AAB and natural attenuation will degrade contaminants and monitoring will be eliminated when the RAOs are met.
• Environmental Protection	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.	The Basewide ERA indicates that there are no elevated risks to ecological receptors from WMU constituents in any media, including groundwater.
ARARs							
• Chemical-Specific ARARs	No chemical-specific ARARs would be met.	Natural attenuation is not considered capable of achieving MCLs, within a reasonable time frame, for all the TA sites, since the rate of TCE migration is greater than the rate of TCE degradation within the plume at the source areas.	This alternative is capable of achieving MCLs within and downgradient of the treatment zone of applicable sites.	This alternative is capable of achieving MCLs, downgradient of the PRBs at applicable sites	This alternative is capable of achieving MCLs.	This alternative is capable of achieving MCLs at applicable sites.	This alternative is capable of achieving MCLs.
• Action-Specific ARARs	There would be no action involved, therefore action-specific ARARs would not be triggered. Does not provide for long-term ground-water monitoring or prevention of exposure.	Long-term groundwater monitoring provided.	The offgas treatment system for the recirculating wells will comply with DRGCAP requirements. Long-term groundwater monitoring provided.	The PRB will comply with DRGHW for active land treatment. Long-term groundwater monitoring provided.	Air stripper system will comply with DRGCAP requirements. Discharge to surface water will comply with Clean Water Act discharge requirements. Long-term groundwater monitoring provided.	Will comply with DRGHW for active land treatment. Long-term groundwater monitoring provided.	Will comply with DRGHW for active land treatment. Long-term groundwater monitoring provided.

Table 10. Comparative Analysis of Alternatives (cont'd)

Criterion	A1 No Action	A2 Natural Attenuation	A4 Groundwater Recirculating Wells	A5 Permeable Reactive Barrier	A6 Groundwater Extraction and Air Stripping	A7 Injection/Diffusion AAB	A8 AAB and Natural Attenuation
Long-term Effectiveness and Permanence							
• Magnitude of risk	Unknown. No mechanism to prevent exposure or monitor groundwater conditions.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential on- and off-Base users will be reduced as contaminant levels are lowered. However, natural attenuation alone is not considered capable of achieving RAOs in the downgradient portion of the plume.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential off-Base and on-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential off-Base and on-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential off-Base and on-Base users will be reduced as contaminant levels are lowered. Constituent concentrations are likely to be decreased considerably after a relatively short operating period, but are likely to rebound to existing concentrations following cessation of pumping activities.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential off-Base and on-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the LUCs provide long-term protection of human health on-Base. Risk for potential off-Base and on-Base users will be reduced as contaminant levels are lowered.
• Reliability of Controls	Unknown. No mechanism to prevent exposure or monitor groundwater conditions.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Because of extensive studies performed by RTDF on natural attenuation within DAFB, a treatability study will not be required for TA 1, 2, 3. Studies will be required for the other applicable sites.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Recirculating well technology is considered reliable.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Because of the extensive study performed on permeable reactive barriers at a WMU site (SS20), a treatability study will not be required. The permeable reactive barrier system at SS20 has been proven effective.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. The extraction system will establish hydraulic control over the source areas in a relatively short time preventing the further migration of contaminants. Air stripping is proven effective for the VOCs and petroleum hydrocarbons.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Site-specific testing of AAB will be required.	LUCs enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Site-specific testing of AAB will be required.
Reduction of Toxicity, Mobility, and Volume							
• Treatment Process Used	Not applicable.	Natural attenuation is not considered a treatment process under the NCP; therefore, not applicable.	Recirculating wells transfer VOCs from aqueous to vapor phase inside the well. Vapors are extracted for treatment by carbon adsorption.	Plumes are captured downgradient by permeable reactive barriers and are treated *in situ* via reductive dehalogenation.	Sites/areas are addressed by groundwater extraction followed by metals pretreatment and air stripping/carbon adsorption.	AAB will augment the aquifer with food source to accelerate biodegradation of contaminants.	AAB and natural attenuation will destroy chlorinated and hydrocarbon compounds at subject sites.
• Reduction in Toxicity, Mobility, and Volume Through Treatment	Not applicable.	Natural attenuation is not considered a treatment process under the NCP; therefore, not applicable.	Recirculating well processes reduce contaminant toxicity. The wells will provide barrier control of the plumes, thereby reducing the mobility and volume of contaminants as they flow through the wall of wells.	*In situ* reductive dehalogenation reduces groundwater toxicity.	Groundwater extraction will provide hydraulic control of the plumes, thereby reducing the mobility of contaminants. Removal of VOCs present in groundwater by air stripping will reduce the toxicity of the contaminant plumes.	AAB will reduce contaminant toxicity. There is no reduction in contaminant mobility or volume.	Reduces contaminant toxicity. There is no reduction in contaminant mobility or volume.

Table 10. Comparative Analysis of Alternatives (cont'd)

Criterion	A1 No Action	A2 Natural Attenuation	A4 Groundwater Recirculating Wells	A5 Permeable Reactive Barrier	A6 Groundwater Extraction and Air Stripping	A7 Injection/Diffusion AAB	A8 AAB and Natural Attenuation
• Irreversibility of Treatment	Not applicable.	Natural attenuation is not considered a treatment process under the NCP; therefore, not applicable.	GRW treatment results in permanent removal of contaminants through irreversible processes.	Reductive dehalogenation results in the permanent removal of contaminants through irreversible processes.	Air stripping treatment results in the permanent removal of contaminants through irreversible processes.	AAB treatment result in the permanent removal of contaminants through irreversible processes.	AAB treatment and natural attenuation result in the permanent removal of contaminants through irreversible processes.
• Type and Quality of Residue	Not applicable.	Not applicable.	Spent activated carbon will be generated from air treatment at the recirculating wells.	No residues generated.	Metals pretreatment generates small volumes of sludge, which will require disposal. Spent activated carbon will be generated from treatment of air stripper offgas and groundwater effluent polishing.	No residues generated. VOC degradation products generated as intermediary contaminants.	No residues generated. VOC degradation products generated as intermediary contaminants.
Short-term Effectiveness							
• Protection of Community During Remedial Action	No short term impact on the community surrounding the site.	No significant risk to the community during construction or operation.	No significant risk to the community during construction or operation.	No significant risk to the community during construction or operation.	No significant risk to the community during construction or operation.	No significant risk to the community during construction or operation.	No significant risk to the community during construction or operation.
• Protection of Workers During Remedial Action	Not applicable.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling. Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction of PRBs.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling.	Standard health & safety procedures and personal protective equipment will prevent exposure during well installations and sampling.
• Environmental Impact	None.	Minimal land disturbance due to installation of wells. Environmental impacts related to construction are minimal.	Minimal disturbance will result from installation of wells. Environmental impacts related to construction are minimal.	Moderate to extensive land disturbance due to installation of PRBs. Minimal disturbance will result from installation of wells. Environmental impacts related to construction are minimal.	Minimal land disturbance due to installation of wells. Environmental impacts related to construction are minimal. Discharge of treated groundwater to surface water/storm sewer not expected to adversely impact the environment.	Minimal land disturbance due to installation of wells. Environmental impacts related to construction are minimal.	Minimal land disturbance due to installation of wells. Environmental impacts related to construction are minimal.

Table 10. Comparative Analysis of Alternatives (cont'd)

Criterion	A1 No Action	A2 Natural Attenuation	A4 Groundwater Recirculating Wells	A5 Permeable Reactive Barrier	A6 Groundwater Extraction and Air Stripping	A7 Injection/Diffusion AAB	A8 AAB and Natural Attenuation
• Time Required to Achieve RAOs	Unknown. This alternative does not monitor for RAO compliance.	The estimated time (in years) to reach RAOs in the source and downgradient plumes are: TA 1,2,3 – >50 / >50 TA 6 – >50 / >50	The estimated time (in years) to reach RAOs in the source and downgradient plumes are: TA 1,2,3 – >50 / >50 TA 6 – >50 / >50 OT28 – 10 years / NA	The estimated time (in years) for constituents to reach RAOs in the upgradient and downgradient plumes are: TA 1,2,3 – >50 / >50 TA 6 – >50 / >50	The estimated time (in years) for constituents to reach RAOs in the source and downgradient plumes are: TA 1,2,3 – >50 / >50 TA 6 – >50 / >50 OT28 – 10 years / NA	The estimated time (in years) for constituents to reach RAOs in the source and downgradient plumes are: TA 1,2,3 – 22 / NE TA 6 – 6 / NA	The estimated time (in years) for constituents to reach RAOs in the source and downgradient plumes are: TA 1,2,3 – 22 / >50 TA 6 – 6 / >50 OT28 – 2 / NA
Implementability							
• Ability to Construct and Operate Technology	Not applicable.	No significant difficulties are anticipated in the physical installation of wells or equipment.	No significant difficulties are anticipated in the physical installation of wells or equipment. Operation of the system is straightforward.	No significant difficulties are anticipated in the physical installation of wells. PRB installation is disruptive to Base operations in the vicinity of PRB.	No difficulties are anticipated in construction of groundwater extraction wells and operation of the air strippers.	No significant difficulties are anticipated in the physical installation of wells or equipment.	No significant difficulties are anticipated in the physical installation of wells or equipment.
• Reliability of Technology	Not applicable.	Natural attenuation has been proven to decrease TCE concentrations upgradient of US Route 113, but is unreliable downgradient of US Route 113. Natural attenuation of petroleum hydrocarbons at DAFB is well-documented.	Groundwater recirculating wells are a reliable technology for removal and destruction of VOCs in homogeneous permeable soils. However, presence of clay layers in the WMU may reduce the reliability of this technology.	Permeable reactive barrier technology is innovative and has been field tested. The technology is simple, and the results from the pilot test at DAFB will assist in the design.	Air stripping provides reliable removal of volatile organic constituents.	The injection/ recirculation AAB studies have been proven effective and reliable in the WMU by the RTDF studies. Injection/diffusion AAB will have to be field tested to demonstrate comparable effectiveness to injection/recirculation AAB.	The injection/ recirculation AAB studies have been proven effective and reliable in the WMU by the RTDF studies. Injection/diffusion AAB will have to be field tested to demonstrate comparable effectiveness to injection/recirculation AAB.
• Ease of Undertaking Additional Action	Not applicable.	Additional actions could easily be performed in areas that were addressed by natural attenuation.	If contaminant levels increase after remediation is complete, additional remediation can be performed by restarting the treatment system. The recirculating well networks may be expanded or replaced with new technologies if necessary.	Placement of the PRBs is permanent. However, additional actions could be performed if necessary.	If contaminant levels increase after remediation is complete, additional remediation can be performed by restarting the treatment system. The well networks may be expanded or replaced with new technologies, if necessary.	If contaminant levels increase after remediation is complete, additional remediation can be performed by injecting additional substrate.	If contaminant levels increase after remediation is complete, additional remediation can be performed by adding additional substrate (AAB).
• Ability to Monitor	Not applicable.	Performance of natural attenuation is easily monitored.	Performance of the technologies is easily monitored.	Performance of the technologies is easily monitored.	Performance of the technologies is easily monitored.	Performance of the technologies is easily monitored.	Performance of the technologies is easily monitored.

Table 10. Comparative Analysis of Alternatives (cont'd)

Criterion	A1 No Action	A2 Natural Attenuation	A4 Groundwater Recirculating Wells	A5 Permeable Reactive Barrier	A6 Groundwater Extraction and Air Stripping	A7 Injection/Diffusion AAB	A8 AAB and Natural Attenuation
• Regulatory Agency Coordination/Approval	None.	Installation of wells will require early coordination with state agencies.	Installation of wells will require early coordination with state agencies.	Installation of wells will require early coordination with state agencies.	Coordination required with DNREC's Air Quality Management Section and with DNREC's NPDES Branch to establish surface water discharge limits.	Coordination with appropriate regulatory personnel in DNREC Underground Injection Section and EPA to achieve approval for use of AAB technology on site. Installation of wells will require early coordination with state agencies.	Coordination with appropriate regulatory personnel in DNREC Underground Injection Section and EPA to achieve approval for use of AAB. Installation of wells will require early coordination with state agencies.
• Availability of Services	Not applicable.	Readily available.	Installation of the recirculating well system will require a specialty contractor, however, the remaining portions of this alternative are readily available.	Installation of the reactive wall will require a specialty contractor.	Air stripping systems are readily available and installation can be easily performed.	Readily available.	AAB is readily available.
• Availability of Equipment	Not applicable.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.
• Availability of Technology	Not applicable.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.
Cost							
Capital Cost:	$0	$252,000	$1,700,000	$11,000,000	$840,000	$2,180,000	$2,180,000
Annual O&M Cost (first year):	$0	$115,000	$190,000	$210,000	$160,000	$300,000	$142,000
Net Present Worth Cost[b]:	$0	$2,780,000	$5,800,000	$16,000,000[a]	$4,300,000[a]	$5,850,000	$6,300,000
State Acceptance – The State of Delaware has expressed its support of the active remedies.							
Community Acdeptance – The community did not express any opinions on the selected remedy.							

TA = Target Area
[a]Does not include costs for the remediation of OT28.
[b]All costs rounded to two significant figures.
DRGHW – Delaware Regulations Governing Hazardous Waste
DRGCAP – Delaware Regulations Governing Control of Air Pollution
NPDES – National Pollutant Discharge and Elimination System

- A1 (No Action) is not protective of human health because it does not contain provisions to eliminate or reduce contamination, nor does it include LUCs to prevent or control human exposure to contaminated soil or groundwater. It also contains no provision to monitor any of the groundwater contaminant plumes, and consequently compliance with RAOs cannot be assessed and future protection cannot be ensured. Therefore, since alternative A1 (No Action) is not protective of human health, it will not be considered further in this analysis.
- A2 (Natural Attenuation) would provide adequate protection of human health by reducing groundwater contaminant levels and establishing LUCs. The LUCs will prevent access to the contaminated groundwater until RAOs are achieved. Calculations presented in the WMU FS indicate that plume discharge to the St. Jones River will not result in the violation of DNREC surface water quality standards, and the GMZ implemented by DNREC will prevent the unauthorized extraction and use of groundwater from the Columbia Aquifer until the plumes have been remediated. Natural attenuation would eventually achieve the RAOs, though an extended period of time is estimated to be required for some of the sites. LUCs would eliminate or control risks to humans from potential exposure to contamination.
- A4 (GRWs) would provide adequate protection of human health. As a barrier technology (with GRWs installed at the downgradient end of the Area 6 plume), this alternative requires more time to achieve RAOs than the more aggressive treatment remedies such as AAB.
- A5 (PRBs) would provide adequate protection of human health. As a barrier technology (with PRBs installed at the downgradient end of the Area 6 plume), this alternative requires more time to achieve the RAOs than the more aggressive treatment remedies such as AAB.
- A6 (Pump & Treat) would provide adequate protection of human health. Surface water discharge of treated groundwater would meet the substantive requirements of Delaware's regulations and would have no negative impact on surface water quality. This alternative requires more time to achieve RAOs than the more aggressive treatment remedies such as AAB.
- A7 and A8 (AAB and Natural Attenuation) would provide good protection of human health, combining the advantages of AAB treatment of the target areas offered by A7 and the advantages of natural attenuation treatment offered by A2 for the remainder of the plume. This process destroys contamination in the ground without having to first extract it from the ground. LUCs would eliminate or control risks to humans from potential exposure to contamination.

2.9.2 Compliance with ARARs

Section 121(d) of CERCLA and NCP § 300.430(f)(1)(ii)(B) require that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate federal and state requirements, standards, criteria, and limitations, or ARARs, unless such ARARs

are waived under CERCLA section 121(d)(4). The "Compliance with ARARs" criterion evaluates whether a remedy will meet all ARARs, or provides a basis for invoking a waiver. Attachment 2 is a list of the ARARs applicable to each site and each of the evaluated alternatives.

Key chemical–specific ARARs applicable to all alternatives are the federal drinking water standards for the chemicals of concern as listed in Table 8. Action-specific ARARs associated with alternatives A7 and A8 include compliance with the substantive requirements of the Delaware Regulations Governing Underground Injection Control because these alternatives involve injection of substrate materials into the aquifer.

Additional action-specific ARARs are associated with Alternatives A4 and A6. Both A4 and A6, require compliance with the substantive requirements of the Delaware Regulations Governing Control of Air Pollution due to air emissions associated with the above-ground treatment systems. A6 also requires compliance with Clean Water Act requirements for discharge to surface water due to the discharge of treated groundwater into the Base stormwater drainage system.

Alternatives A2 through A8 would all achieve compliance with ARARs, though the time required to meet groundwater RAOs varies between alternatives as discussed in Section 2.9.5.

2.9.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers the magnitude of residual risk that would remain after the implementation of an alternative, and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met. All of the action alternatives provide for the long-term protection of human health on-Base through LUCs and off-Base through DNREC's GMZ. The treatments provided by Alternatives A2 through A8 are all considered adequate and reliable.

2.9.4 Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Alternatives A4 through A8 all use treatment to reduce toxicity, mobility, or volume of contaminants and therefore satisfy the preference for active treatment. Alternative A2 can reduce toxicity and volume of contaminants, but is not considered a treatment process under the NCP. For a brief discussion of each alternative see Table 10.

2.9.5 Short-Term Effectiveness

Short-term effectiveness examines the period of time needed to implement the remedy and impacts to workers and the community and environmental health during construction and operation of the remedy and the time required to achieve RAOs. None of the alternatives will significantly impact either worker or community or environmental

health. Therefore, the evaluation of this criterion focuses on the estimated remediation times.

A summary of the estimated remediation times is presented in Table 11. Separate remediation times are estimated for the target areas and downgradient portions of the plume. The primary differences in the estimated times are found in the comparison of source remediation times. The downgradient plume remediation times tend to be extended for all action alternatives due to the very large size of the Area 6 plume. Consequently, the evaluation of this criterion focuses on the source area remediation times.

Table 11. Times to Achieve RAOs (in years)

Alternative	Target Area 1,2,3	Target Area 6
A2	>50 / >50	>50 / >50
A4	>50 / >50	>50 / >50
A5	>50 / >50	>50 / >50
A6	>50 / >50	>50 / >50
A7	22 / NE	6 / NE
A8	22 / >50	6 / >50

NE - Not evaluated
Note: RAO times are given for the source area of the plume followed by the downgradient portion of the plume; e.g., 22/>50 means 22 years for the remediation of the source and more than 50 years for the downgradient portion of the plume.

A7 (AAB) and A8 (AAB and Natural Attenuation) provide the fastest remediation times for the target/source areas within Area 6. These alternatives are most efficient at treating the source areas, achieving RAOs within an estimated range of 6 to 22 years. All of the flow-based remedies that rely upon the migration of source-area contaminants to be remediated take much longer to achieve RAOs.

2.9.6 Implementability

The main factors considered for this criterion are technical feasibility and administrative feasibility. The concept of administrative feasibility includes such implementation actions as modifying the Base General Plan to identify LUCs and coordinating specific LUC language issues, and complying with annual LUC monitoring and reporting requirements with federal and state regulators, and availability of required services and materials. All alternatives are administratively feasible. Therefore, the focus of this comparison is on the technical feasibility of implementing the alternatives.

A2 (Natural Attenuation) has only minimal technical considerations. A4 (GRWs) and A6 (Pump & Treat) are the most complex systems to design, construct, and operate. A7/A8 (AAB and Natural Attenuation) both present considerable implementability challenges because they involve chemical injection at numerous injection points, all of which must be clear of utilities and infrastructure. A5 (PRBs) is the most difficult alternative to implement because the PRB systems must be excavated to the confining clay layer (about 45 ft bgs) over extended areas and across lengths that will undoubtedly impact

infrastructure and Base operations. Once installed, operation of the PRBs is relatively easy.

2.9.7 Cost

The costs associated with each action alternative are summarized in Table 12. Capital costs reflect the estimated expenses for construction or implementation of a remedy including equipment, supplies, and labor. The annual O&M costs are those required for routine maintenance of equipment and regular monitoring of a remedy's performance, which includes periodic groundwater sampling. Net present worth is the total remedy cost (capital and O&M) assuming that the funds set aside today would grow at a certain percentage rate and that the annual O&M costs would remain unchanged over the years of remedy operation. A discount rate of 4 percent was used in this calculation. The net present worth calculation extends out to 50 years. The effect of the discount rate makes costs beyond 30 years negligible in the net present worth calculation.

Table 12. Cost Summary

Alternative	Capital Cost	Annual O&M	Present Worth
A2	$252,000	$115,000	$2,780,000
A4	$2,340,000	$233,000	$6,800,000
A5	$11,000,000	$210,000	$16,000,000
A6	$1,290,000	$211,000	$5,160,000
A7	$2,180,000	$300,000(a)	$5,850,000
A8	$2,180,000	$192,000(a)	$6,300,000

(a) Estimate is complex due to timing of injections; an average O&M cost is shown.

The simple comparison of alternative costs in Table 12 is somewhat misleading because the alternatives do not all address the same sites; some of the alternatives are only applicable to selected target areas or site groupings. In order to more fully assess remediation costs, a breakdown of costs by site is presented in Table 13. When the Area 6-wide remedy is implemented, each site will need to be addressed. Two of the alternatives (A5 and A7) which address all of the Area 6 sites except OT28 would have to be supplemented with other alternatives. For example, if Alternative A7 is selected for implementation ($5.8 million net present worth), another alternative would still need to be selected to address OT28. Thus, the costs presented in Tables 12 and 13 for A5 and A7 slightly under-report the complete Area 6 remedial cost.

2.9.8 State Agency Acceptance

The Delaware DNREC supports the selection of Alternative A8 (AAB, Natural Attenuation with Monitoring, and LUCs) for the Area 6 sites.

TABLE 13. Action Alternatives Cost Summary by Target Area/Site

Alternative	A2. Natural Attenuation	A4. GRW	A5. PRB	A6. Groundwater Extraction & Air Stripping	A7. AAB	A8. AAB and Natural Attenuation
			Target Area 1,2,3			
Capital Cost	$16,000	$1,700,000	$11,000,000	$840,000	$1,800,000	$1,800,000
Annual O&M	$79,000	$190,000	$210,000	$160,000	$248,000	$158,000
Present Worth	$1,710,000	$5,800,000	$16,000,000	$4,300,000	$5,100,000	$5,300,000
			Target Area 6			
Capital Cost	$236,000	Cost included in Target Area 1,2,3	Cost included in Target Area 1,2,3	Cost included in Target Area 1,2,3	$380,000	$380,000
Annual O&M	$36,000				$52,000	$34,000
Present Worth	$1,010,000				$750,000	$1,000,000
			OT28			
Capital Cost	Cost included in Target Area 1,2,3	$640,000	Not applicable	$450,000	Not applicable	Cost included in Target Area 1,2,3
Annual O&M		$43,000		$51,000		
Present Worth		$990,000		$860,000		

Note: Remedy costs were assessed primarily on a target-area basis rather than site by site. Target Area 1,2,3 includes WP21, ST34, OT41/Bldg. 719, and SS59. Target Area 6 does not encompass an ERP site but it is downgradient of WP31 and OT48. OT28 is at the toe of the Area 6 plume, downgradient of the two target areas.

2.9.9 Community Acceptance

Community acceptance of the recommended alternative, A8 (AAB, Natural Attenuation with Monitoring, and LUCs) was evaluated after the public comment period and public meeting for the Proposed Plan were completed. As described in Part III - Responsiveness Summary of this ROD, no comments were received.

2.10 PRINCIPAL THREAT WASTES

The NCP establishes an expectation that treatment will be used to address the principal threats (i.e. source material that is highly toxic and/or highly mobile) posed by a site wherever practicable. Principal threat wastes may be present at one of the Area 6 sites: OT41/Bldg. 719. This single largest contributor to the Area 6 plume appears to exist below Building 719, an active maintenance facility. Based on the subsurface data collected below the building's foundation, it is likely that the release of solvents from the former degreasing operation passed quickly through the gravel sub-base and into the zone of soil affected by the natural fluctuations of the water table. The AAB treatment system described in Section 2.8.1.9 is currently in operation and treating the source area at OT41/Bldg. 719. Data from the site indicates that as the water table fluctuates up and down, solvents are flushed from the soil and into the groundwater where they are captured in the recirculating treatment cell.

At SS59, source materials in shallow soil were identified that may have posed a continuing threat to groundwater. As described in Sections 2.3 and 2.8.1.10, a soil removal and capping action was accomplished at SS59 to mitigate this potential threat.

Continued operation of the AAB treatment system at OT41/Bldg. 719 and maintenance of the asphalt cover at SS59 are components of the selected remedy in this ROD. Thus, in accordance with the NCP, treatment has been and is being used to address the potential principal threats within Area 6.

2.11 SELECTED REMEDY

2.11.1 Summary of the Rationale for the Selected Remedy

Alternative A8 (AAB, Natural Attenuation with Monitoring, and LUCs) is the selected remedial alternative for the Area 6 sites based on the comparison of alternatives discussed in Section 2.9. Alternative A8 addresses all of the Area 6 sites and is recommended based on the best blend of effectiveness, implementability, and cost. With injection/diffusion AAB treatment proposed under A8, the estimated remediation time for the source areas is much shorter relative to natural attenuation alone or the flow-based alternatives that are available. The present worth cost of A8 ($6,300,000) is comparable to the costs of competing alternatives A4 and A6, and much less than alternative A5, that do not deliver the performance nor as comprehensively address contamination as A8. Source area treatment with AAB will significantly reduce contaminant mass where feasible and cost effective. A8 will be more difficult to implement than the flow-based

remedies A4 and A6, but this is not judged to outweigh the cost and performance benefits provided by the A8 alternative. In all, alternative A8 is judged to provide the best balance of tradeoffs among the nine evaluation criteria, and is therefore the selected alternative.

LUC performance objectives will protect human health and the environment while the active portion of the remedy is undertaken by ensuring that on-Base land-use is restricted to industrial purposes, with on-site day-care centers, schools, and recreation areas prohibited. Digging and other ground-disturbing activities that are inconsistent with the LUC objectives at these sites are prohibited. The LUC performance objectives will also prohibit the use of groundwater from the Columbia Aquifer near these sites until and unless it is demonstrated that the CERCLA hazardous substances at the sites are below levels allowing for unrestricted exposure and unlimited use. The LUC performance objectives will also maintain the integrity of any current and future remedial or monitoring system. The LUC portion of the remedy is easily implemented and has very minimal costs associated with it.

2.11.2 Description of the Selected Remedy

The selected remedy for Area 6 is Alternative A8, AAB and Natural Attenuation with Monitoring and LUCs. The layout of this alternative across Area 6 within the Base boundary is shown in Figure 3. The estimated time frames to achieve RAOs using alternative A8 range from 6 to 22 years for target/source areas and over 50 years for the downgradient portion of the plumes (Table 11). Alternative A8 includes the following major components:

- **Injection/Diffusion AAB at Target Area 1,2,3 and Target Area 6 source areas.** AAB will be applied where the contaminant concentrations are most elevated within the Area 6 plume. AAB involves the injection of a carbon-containing substrate into the groundwater to create an anaerobic environment, thereby enhancing microbial activity and stimulating reductive dechlorination of the contaminants. Conceptually, injection points will be laid out in a series of barrier rows crossing the target areas perpendicular to groundwater flow. If each barrier consists of two offset rows (200 ft apart) of injection points that are 15 ft apart along each row, it will take approximately 2,053 injection points to cover Target Area 1,2,3 and about 378 points for Target 6. Exact placement and numbers of injection points, as well as substrate material and quantity, will be developed as part of the remedial action work plan for the Area 6 plume, which will be reviewed and approved by USEPA and DNREC. It is expected that periodic injections of substrate will be required over several years to reduce total chlorinated ethene concentrations to below approximately 500 μg/L in target area monitoring wells. During the injection process, conditions that favor anaerobic degradation will need to be maintained. Typically optimum conditions include dissolved oxygen less than 1.0 mg/L, oxidation reduction potential less than -200 millivolts (mV), and pH greater than 6.0 but less than 8.0, but these parameters may vary from site to site while anaerobic degradation is maintained. Therefore, monitoring will include measurement of these indicator parameters as well as

total organic carbon levels and concentrations of biodegradation daughter products (e.g.. cis-1,2-DCE, and vinyl chloride) to verify that anaerobic biodegradation is established and maintained. Once total chlorinated ethene concentrations are reduced to below approximately 500 ug/L using AAB, natural attenuation will be used to treat the residuals to RAO concentrations.

- **AAB Injection/Recirculation System at OT41/Bldg. 719.** The treatment system installed at OT41/Bldg. 719, which is located at the upgradient tip of Target Area 1,2,3, will continue to be operated. This system is part of the Target Area 1,2,3 remedy, and it will be turned off once total chlorinated ethene concentrations fall below 500 μg/L within the treatment cell. During the injection process monitoring, conditions that favor anaerobic degradation will need to be maintained. Typically optimum conditions include dissolved oxygen less than 1.0 mg/L, oxidation reduction potential less than -200 mV, and pH greater than 6.0 but less than 8.0, but these parameters may vary from site to site while anaerobic degradation is maintained. Therefore, monitoring will include measurement of these indicator parameters as well as total organic carbon levels and concentrations of biodegradation daughter products (e.g.. cis-1,2-DCE, and vinyl chloride) to verify that anaerobic biodegradation is maintained. Once total chlorinated ethene concentrations are reduced to below approximately 500 ug/L using AAB, natural attenuation will be used to treat the residuals to RAO concentrations. If concentrations rebound, the system can be restarted.
- **Maintain the Existing Cover at Site SS59.** To reduce infiltration and prevent unacceptable human exposures, DAFB will ensure the integrity of the asphalt cover system at this site.
- **Natural Attenuation of the Area 6 Plume Outside the Target Areas.** Naturally occurring biological and physical processes are expected to reduce contaminant concentrations in all groundwater contaminant areas not treated using AAB. Evidence for the occurrence of these processes in Area 6 was documented in the RTDF natural attenuation study reports (RTDF, 1997). Groundwater monitoring will be conducted to verify the effectiveness of the natural attenuation remedy.
- **Groundwater Monitoring.** Periodic groundwater monitoring will be accomplished at Area 6. Approximately six new monitoring wells will be installed to supplement the existing well network, and groundwater monitoring will be performed on approximately 33 wells. The conceptual monitoring well networks, including recommendations for new wells, are shown for Area 6 in Figure 3. Groundwater samples will be analyzed for chlorinated VOCs, aromatic hydrocarbons (fuel-related VOCs, particularly benzene), and Lindane (a pesticide) as appropriate for the various portions of the Area 6 plume. Analysis will also be performed for anaerobic biodegradation indicators (e.g., dissolved oxygen, redox potential, iron, etc.). The exact placement and number of monitoring wells, sampling frequency, and other monitoring details will be developed as part of the remedial action work plan for Area 6.
- **LUCs** for soil and groundwater as described in Section 2.8.1.11.

- **No Further Action** is required for the soil medium at OT28.
- Potential human health risk associated with vapor intrusion from subsurface contamination into buildings is not fully addressed in this ROD. The Air Force will evaluate the vapor intrusion pathway for the Area 6 sites during the groundwater remedial action phase of the cleanup program.

Under the selected remedy, the time frames to achieve RAOs in Area 6 are estimated to range from 6 to 22 years for target area plumes, to over 50 years for the downgradient plume (Table 11).

2.11.3 Summary of the Estimated Remedy Costs

A summary of the costs for the selected remedy is provided in Table 14. The capital costs shown in the table are primarily associated with installation of new monitoring wells within Area 6, and the installation of injection points and initial carbon-substrate injection at the target areas. Subsequent substrate injections and periodic monitoring are considered O&M costs.

The costs shown in Table 14 are based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during the engineering design of the remedial alternative. Major changes may be documented in the form of a memorandum in the Administrative Record file, an Explanation of Significant Differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.

2.11.4 Expected Outcomes of the Selected Remedy

Once the LUCs portion of the remedy is in place, land use at Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, and SS59 will be restricted to industrial uses and land use at OT28 will be unrestricted for industrial or residential use. Additionally, the asphalt cover at SS59 will be maintained. The LUCs will remain in effect until concentrations of hazardous substances at these sites are shown to be at levels allowing for unrestricted exposure and unlimited use.

For contaminants in groundwater at all seven Area 6 sites, natural attenuation and AAB will reduce concentrations to the RAOs established for the Area 6 sites. The RAOs, which are based on the federal MCLs for safe drinking water, are listed in Table 8. Thus, once the RAOs are achieved, on-Base groundwater from the Columbia Aquifer would be available for unrestricted use. Estimated times to achieve the RAOs vary by site and are listed in Table 11. Off-site migration of contaminated groundwater at levels exceeding MCLs will no longer be a concern once groundwater RAOs are achieved. Therefore, restrictions on use of the Columbia Aquifer in off-Base areas identified in the DNREC GMZ for Dover AFB could be lifted assuming there are no issues with non-Air Force off-Base sources of contamination.

Table 14. Cost Estimate for Alternative A8

		Target Area 1,2,3 (includes WP31, OT28)		Target Area 6	
CAPITAL COSTS	**Unit Cost**	**Units**	**Total**	**Units**	**Total**
A. Construction Costs - HRC Placement					
Pilot Study (1)	10,000 /each	1	10,000	1	10,000
Installation of Injection Points (2)	200 /point	2,052	410,400	378	75,600
HRC (1)	6 /pound	125,000	750,000	20,000	120,000
Subtotal			***1,170,400***		***205,600***
B. Long-term Monitoring Well Installation					
Columbia Aquifer Well	7,500 /each	0	0	5	37,500
Frederica Aquifer Well	16,000 /each	1	16,000	0	0
Subtotal			***16,000***		***37,500***
Total Construction Cost			***1,186,400***		***243,100***
Health & Safety Contingencies (2.5%)			29,700		6,100
Construction Contingencies (20%)			237,300		48,600
Design Engineering & Construction Management (25-35%)			296,600		85,100
Total Capital Cost (rounded)			**1,800,000**		**380,000**
OPERATIONAL COSTS					
C. HRC Treatment (in 2nd year only)					
Installation of Injection Points (2)	200 /point	2,052	410,400	378	75,600
HRC per Point (1)	6 /pound	125,000	750,000	20,000	120,000
Health & Safety Contingencies (2.5%)			29,000		4,900
Construction Contingencies (20%)			232,100		39,100
Design Engineering & Construction Management (35%)			290,100		68,500
Subtotal (in 3rd year only)			***1,190,000***		***201,000***
D. HRC Treatment (in 4th year only)					
Installation of Injection Points (2)	200 /point	2,052	410,400	0	0
HRC per Point (1)	6 /pound	125,000	750,000	0	0
Health & Safety Contingencies (2.5%)			29,000		0
Construction Contingencies (20%)			232,100		0
Design Engineering & Construction Management (35%)			290,100		0
Subtotal (in 5th year only)			***1,190,000***		***0***
E. Long-Term Groundwater Monitoring					
Number of Wells Sampled			23		10
Sample Collection Labor (2 times/year)	500 /well	46	23,000	20	10,000
Laboratory Analyses Including QA/QC Samples	500 /sample	64	32,000	28	14,000
Sampling & Monitoring Report	3,000 /6 wells	8	24,000	4	12,000
Groundwater Monitoring Subtotal			***$79,000***		***$36,000***
Time to Reach RAOs (yrs; source area/downgradient plume)		22	50	6	50
Net Present Worth (rounded) (3)			**5,300,000**		**1,000,000**

(1) HRC = Hydrogen Release Compound ™. Vendor quote for costing purpose only, Regenesis 2003. Alternate material may be selected during the remedial design phase.

(2) Quote from Regenesis assumes a geoprobe cost of $2,000 per day which will complete 10 points per day.

(3) Net present worth for groundwater monitoring is based on a 4% interest rate. Where RAO times differ for source and downgradient portions of plume, annual groundwater monitoring costs are reduced by 50% for the longer portion of the remediation program.

2.12 STATUTORY DETERMINATIONS

This section provides a brief, site-specific description of how the selected remedy satisfies the statutory requirements of CERCLA Section 121 (as required by NCP §300.430(f)(5)(ii)) for protection of human health, compliance with ARARs, cost-effectiveness, and use of permanent solutions/alternative treatments/resource recovery technologies to the maximum extent practicable.

Of those alternatives that are protective of human health and the environment and comply with ARARs, the USAF has determined that the selected remedy (AAB, Natural Attenuation with Monitoring and LUCs) provides the best balance of tradeoffs in terms of the five balancing criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume of contaminants through treatment; short-term effectiveness; implementability; and cost) while also considering the statutory preference for treatment as a principal element, the bias against off-site treatment and disposal, and considering regulatory and community acceptance.

All of the evaluated alternatives except No Action (A1) and Natural Attenuation (A2) would provide excellent performance relative to the criteria of long-term effectiveness and permanence and reduction of toxicity, mobility, or volume through treatment. All alternatives except No Action and Natural Attenuation involve the permanent reduction of groundwater contaminant levels through treatment. Therefore, the most decisive criteria in evaluating the best balance of tradeoffs are short-term effectiveness, implementability, and cost. The selected remedy provides the best blend of these criteria, providing good short-term effectiveness by reducing groundwater contaminant levels, being readily implementable, and costing only slightly more than most of the other options while providing much improved remediation times relative to other alternatives.

2.12.1 Protection of Human Health and Environment

The selected remedy for Area 6 and its seven associated sites is protective of human health and the environment. It will achieve protection by reducing groundwater contaminant concentrations through treatment, thereby reducing risks posed by potential exposure to groundwater at the seven Area 6 sites. Groundwater contaminants at all sites will be reduced through natural attenuation processes and treated by AAB at the two target areas. Groundwater exposure levels will be reduced to protective ARAR levels via these remedial actions. LUCs will be implemented to prevent human exposure to contaminated groundwater until cleanup levels are achieved. LUCs will also be implemented to prevent or control potential human exposure to residual contaminants in soil, and prevent incompatible use of the sites, except at OT28 where no further action is required for soil. At SS59, maintenance of the asphalt cover is also part of the soil remedy to prevent unacceptable human exposure to residual pesticides in soil. At OT41/Bldg. 719 soil is also being treated by the AAB recirculation system. Implementation of this remedy will not pose any unacceptable short-term risks or cross-media impacts.

2.12.2 Compliance with ARARs

CERCLA Section 121(d)(2)(A) specifies that on-site remedial actions be evaluated to determine whether they meet standards, requirements, criteria, or limitations under any federal environmental law that is determined to be an ARAR. This provision also specifies that State ARARs must be met if they are more stringent than federal requirements.

ARARs are typically divided into three categories: 1) those that pertain to the management of certain chemicals; 2) those that control specific actions; and 3) those that restrict certain activities at a given location. Chemical-specific ARARs are typically numerical (risk-based) values or methodologies that establish limits on the concentrations of a chemical discharged to or found in the environment. Action-specific ARARs are technology or activity-based requirements and limitations on actions taken involving the management of hazardous wastes. Location-specific ARARs are restrictions placed on the conduct of activities in unique or sensitive areas to prevent damage in that area.

The selected remedy of AAB, natural attenuation, and LUCs, complies with federal and State ARARs. A comprehensive list of federal and State ARARs applicable to the Area 6 sites and the remedial alternatives is included in Attachment 2; ARARs applicable to the selected alternative are identified as such in the attachment. The major ARARs applicable to the Area 6 sites and selected remedy are described below.

2.12.2.1 Chemical-Specific ARARs

- Federal Safe Drinking Water Act, National Primary Drinking Water Regulations (40 CFR Part 141)—Establishes primary drinking water standards such as MCLs. The selected remedy will attain the quantitative groundwater RAOs described in Section 2.7 and listed in Table 8. These quantitative RAOs are based on the federal MCLs for the COCs at each site.
- Chapter 91, Delaware HSCA (1995), the Delaware Regulations Governing HSCA—Establishes risk-based and chemical-specific remediation standards applicable to sites where hazardous substances have been released. Delaware chemical-specific remediation standards established under HSCA are equivalent to federal MCLs for the COCs in groundwater at the Area 6 sites. The selected remedy will attain the quantitative groundwater RAOs listed in Table 8, which will satisfy State risk-based and chemical-specific remediation standards.

2.12.2.2 Action-Specific ARARs

- Federal Safe Drinking Water Act, Underground Injection Control (UIC) (40 CFR Parts 144 and 146) —Establishes technical criteria and standards for underground injection. Application of the AAB technology at the target areas involves underground injection of a carbon substrate which will be accomplished in accordance with UIC requirements.

- Delaware Regulations Governing the Construction and Use of Wells (1997)—Establishes requirements for the location, design, installation, use, modification, repair, and abandonment of groundwater wells and associated equipment. Wells installed under the selected remedy will comply with these regulations.
- Delaware Regulations Governing Hazardous Waste (DRGHW), Groundwater Protection (DRGHW Part 264.b Subpart F)—Establishes groundwater monitoring criteria. The selected remedy includes groundwater monitoring at all seven of the Area 6 sites.
- DRGHW Closure and Post Closure—DNREC issued a RCRA post-closure permit for WP21, requiring post-closure care and groundwater corrective action. Actions taken at this site will comply with the substantive requirements of the DRGHW for post-closure care and groundwater corrective action. Upon implementation of the AAB remedy at WP21, DNREC and DAFB have agreed to terminate the RCRA post-closure permit for WP21, and conduct future actions under this ROD and CERCLA requirements.

2.12.2.3 Location-Specific ARARs

- Requirements for Wetlands and Floodplains (40 CFR Part 6 – National Environmental Policy Act §6.302) – Establishes requirements to avoid adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists. This ARAR is applicable to Site OT28 which is adjacent to wetlands and is located in a 100-year floodplain. The selected remedy will not adversely affect the wetland or floodplain areas.

2.12.3 Cost-Effectiveness

In the USAF's judgment, the selected remedy is cost-effective and represents a reasonable value for the money to be spent. According to NCP §300.430(f)(1)(ii)(D), a remedy is considered cost effective if its "costs are proportional to its overall effectiveness." The overall effectiveness of those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment and ARAR-compliant) was evaluated by assessing three of the five balancing criteria used in the analysis of alternatives: long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness. Overall effectiveness was then compared to costs to determine cost-effectiveness. The relationship of the overall effectiveness of the selected remedy was determined to be proportional to its costs and hence this alternative represents a reasonable value for the money to be spent.

Table 15 summarizes the cost-effectiveness determination for the selected remedy. The estimated present worth cost of the selected remedy is $6,300,000. This includes the capital costs as well as the O&M costs estimated over the length of time required to achieve RAOs at Area 6 and associated sites.

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Table 15. Cost and Effectiveness Matrix for Area 6 Remediation Options

Relevant Considerations for Cost Effectiveness Determination:

(1) The Area 6 groundwater contaminant plume comprises two target areas of higher concentrations surrounded by areas of lower concentrations.
(2) The primary factor for differentiating cost is the method of source treatment, which is most relevant to short-term effectiveness and the time required to meet RAOs.
(3) Treatment options for the portion of the plume away from the target areas are limited due to the generally low levels of contamination over relatively large areas.
Note: Alternative A3 does not appear in this table because it was not evaluated for Area 6.

Alternative	Cost Effective?	Present Worth Cost	Incremental Cost	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness
A1 - No Action	No	$0	$0	Alternative provides no mechanism to determine reduction in long-term risks to human health or the environment.	NA	*No short-term risks to workers, community, or environment. *Time to achieve RAOs is unknown with this alternative.
A2 - Natural Attenuation	Yes	$2,720,000	$2,720,000	(1) All action alternatives are long-term and permanent solutions for groundwater contamination. (2) LUCs are effective in restricting exposures as required by the soil and groundwater RAOs (see Section 2.7). (3) LUCs will remain in place until land uses change or until contaminant levels fall below the levels allowing for unrestricted or unlimited use.	Reductions in toxicity and volume of contaminants are achieved with all six action alternatives except for the following alternative-site combinations: A5 - OT28 A7 - OT28	= No short-term risks to workers, community, or environment. = RAOs will be achieved with this alternative although extended periods of time are required because the TCE portion of the plume has not stabilized.
A6 - Groundwater Extraction & Air Stripping	Yes	$5,160,000	$2,440,000			= No short-term risks to workers, community, or environment. = RAOs will be achieved with this alternative although extended periods of time are required.
A4 - GRW	Yes	$6,800,000	$1,640,000			= No short-term risks to workers, community, or environment. = RAOs will be achieved with this alternative although extended periods of time are required.
A7 - AAB	Yes	$5,850,000	-$950,000			= No short-term risks to workers, community, or environment. + RAOs are achieved more quickly, 6 to 22 years within the target areas where AAB is applied. - Unsuitable for OT28. - Does not address distal portion of Area 6 plume.
A8 - AAB & Natural Attenuation	Yes	$6,300,000	$450,000			= No short-term risks to workers, community, or environment. + RAOs are achieved more quickly, 6 to 22 years within the target areas where AAB is applied. + Suitable for OT28.
A5 - PRB	Yes	$16,000,000	$9,700,000			= No short-term risks to workers, community, or environment. - RAOs will require extended periods of time compared to previous two alternatives. - Unsuitable for OT28.

Cost Effectiveness Summary:

(1) All six action alternatives (A2, and A4 through A8) are cost effective.

(2) Alternatives A2, A4, and A6 are only slightly less costly than A7 and A8 and do not deliver the enhanced performance in the target area obtained with A7/A8.

(3) A5 is the most costly alternative and underperforms in the target areas relative to the AAB options.

(4) A8 combines the best of alternatives A2 and A7. Overall plume remediation times are comparable to other alternatives, with a particular improvement of the remediation time for the target areas.

Key:
* Baseline characteristic
+ More effective than previous alternative
- Less effective than previous alternative
= No change compared to previous alternative
NA - Not Applicable

Although the other action alternatives (with the exception of A5, PRBs) are less expensive, the times to achieve RAOs with these alternatives are significantly longer for the target areas. In addition, alternative A7 does not address groundwater contamination at OT28. The USAF believes that the selected remedy (A8, AAB and Natural Attenuation with Monitoring and LUCs) will provide an overall level of protection comparable to other alternatives in a much more timely manner with only a relatively small increase in total cost.

2.12.4 Use of Permanent Solutions and Alternative Treatment Technologies

The USAF has determined that the selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be practicably used at Area 6.

2.12.5 Preference for Treatment as a Principal Element

The selected remedy somewhat satisfies the statutory preference for treatment as a principal element of the remedy. There are no source materials constituting principal threats at six of the seven Area 6 sites. The selected remedy satisfies the statutory preference for treatment by applying AAB as groundwater treatment remedies at both target areas. The one location where source materials constituting principal threats may be present (OT41/Bldg. 719) will continue to be treated via the existing AAB recirculation system. Groundwater target areas within the plume will be treated using AAB. The remaining plume will be addressed via natural attenuation. These groundwater remedies are expected to reduce the toxicity, mobility, and volume of the groundwater contaminants to levels meeting ARARs.

2.12.6 Five-Year Review Requirements

Because the selected alternative will result in hazardous substances remaining on-site above levels that allow for unrestricted exposure and unlimited use, a statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health and the environment. Five-Year Reviews will be conducted until concentrations of hazardous substances in soil at the sites are at levels allowing for unrestricted exposure and unlimited use, and cleanup levels (shown in Table 8) for the contaminants in the aquifer have been achieved.

2.13 DOCUMENTATION OF SIGNIFICANT CHANGES TO THE SELECTED REMEDY FROM THE PREFERRED ALTERNATIVE OF THE PROPOSED PLAN

The Proposed Plan for Area 6 was released for public comment in July 2005. A public meeting was held on July 19, 2005. The Proposed Plan identified Alternative A8 – AAB with Natural Attenuation – as the preferred alternative for the Area 6 sites. No written or oral comments were received during the public comment period or during the public meeting. It was determined that no significant changes to the remedy, as originally identified in the Proposed Plan, were necessary or appropriate.

PART III: RESPONSIVENESS SUMMARY

The Proposed Plan for Sites WP21, WP31, ST34, OT41/Bldg. 719, OT48, SS59, OT28, and Area 6, Dover Air Force Base, Delaware (AFCEE, 2005), was made available to the public for review and comment from July 10 through August 24, 2005. A public meeting was held on July 19, 2005, at 6:30 p.m. at the DNREC auditorium, 89 Kings Highway, Dover, Delaware. No written or oral comments were received from the community during the public comment period or at the public meeting. No regulatory agency or legal issues have been identified. This ROD documents the selected remedy with no changes from the Proposed Plan.

ATTACHMENT 1 - REFERENCES

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HAZWRAP, 1996. Results of Lindane Source Area Investigation, submitted by HAZWRAP, August 1996.

HAZWRAP, 1993. Ecological Risk Assessment, Phase I: Site Characterization, Dover AFB, Dover, Delaware, submitted by Dames & Moore, February 1993.

HAZWRAP, 1991. Site Investigation Reports for WP31, OT41, OT48, and OT28, submitted by Dames & Moore, September 1991.

HAZWRAP, 1990. Installation Restoration Program, Draft Technical Memorandum: Sampling and Data Results, Sites T-1, SP-9, D-4, and DD-1, Dover Air Force Base, Delaware, submitted by E.C. Jordan and C.C. Johnson & Malhotra, February 1990.

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RTDF, 1997. Natural Attenuation Study Reports, submitted by the RTDF circa 1997.

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SAIC, 1986. USAF Installation Restoration Program – Dover AFB, Delaware, Phase II – Stage I Confirmation/Quantification.

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USACE, 1999a. Target Area 1 – SS59 Site Investigation Summary Report, Dover Air Force Base, Delaware, submitted by Dames & Moore, August 1999.

USACE, 1999b. Summary Report Source Characterization of Target Areas 2 and 3, Dover Air Force Base, Delaware, submitted by Dames & Moore, March 1999.

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ATTACHMENT 2

ARARs

Table 2a. Federal ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Status (1)
The federal ARARs for the **Resource Conservation and Recovery Act (RCRA)** program are the State of Delaware regulations listed in Table 2b, since the authorized State program is the federally enforceable program.		R/A
Title 40 – Protection of Environment, Chapter I – Environmental Protection Agency		
Safe Drinking Water Act (SDWA)		
1. Part 144 – Underground Injection Control (UIC)	Substrate will be injected into groundwater to promote biodegradation of contaminants.	
144.3 -- Definitions	Defines terms used in these regulations.	A
144.6 -- Classification of wells	Wells used for injection are Class V wells.	A
144.12 – Prohibition of movement of fluid into underground source of drinking water (USDW)	Injection of fluid may not cause violation of any primary drinking water regulation.	A
144.26 – Inventory requirements	Requires submission of inventory of wells including construction parameters and injection practices. Comply with substantive requirements to inventory wells	A
144.27 – Requiring other information	Comply with substantive additional information requirements, including groundwater monitoring, injectate analysis, and a description of the geology of the receiving formation.	A
144.51 – Conditions applicable to all permits	Well construction, operation and maintenance, and abandonment should comply with the substantive requirements of this section.	A
144.52 – Establishing permit conditions	Well construction, operation and maintenance, and abandonment should comply with the substantive requirements of this section.	A
144.81—Requirements for Class V wells	Defines injection wells used in experimental technologies as Class V wells.	A
144.82 – Protection of USDWs	Injection of fluid may not cause violation of any primary drinking water regulation.	A
2. Part 146 – Underground injection control program: Criteria and standards	Identifies technical criteria and standards for the UIC Program.	
146.3 -- Definitions	Defines terms used in these regulations.	A
146.5 – Classification of injection wells	Defines injection wells used in experimental technologies as Class V wells.	A
146.6 – Area of review	Requirement to calculate the area impacted by the injection.	A
146.8– Mechanical integrity	Requirements for adequate well construction and maintenance.	A
146.10(c) – Plugging and abandoning Class V wells	Requirements for well closure.	A
3. Part 147 – State UIC Programs		

(1) A = Applicable R/A = Relevant and Appropriate

Table 2a. Federal ARARs (cont'd)

Environmental Laws and Regulations	Consideration as an ARAR	Status (1)
147.400 – Delaware State UIC Program	State program incorporated by reference into the federal regulations: State of Delaware Regulations governing Underground Injection Control, Parts 122 and 146 as itemized under State ARARS, Table 2b.	A
4. Part 141 – National primary drinking water regulations	Establishes primary drinking water regulations pursuant to the SDWA such as maximum contaminant levels (MCLs). Some constituents exceed their MCLs in groundwater.	
141.2 -- Definitions	Defines terms used in these regulations.	R/A
141.24 – Organic chemicals, sampling and analytical requirements	Contaminants in the aquifer are volatile organic compounds.	R/A
141.27 – Alternate analytical techniques	Alternate analytical techniques may be used as described.	R/A
141.28 – Certified laboratories	Requirement that samples be analyzed by certified State laboratories.	R/A
141.50 – MCLGs for organic contaminants	CERCLA requires groundwater cleanups to attain MCLGs where relevant and appropriate.	R/A
141.61 – MCLs for organic contaminants	MCLs are the RAOs for the volatile organic compounds found in the groundwater at the Site.	R/A

(1) A = Applicable R/A = Relevant and Appropriate

Table 2b. State ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Status (1)
A. Delaware Regulations Governing Solid Waste		
1. Section 6: Industrial Landfills		
k. Post-Closure Care	Minimum post-closure care requirements include maintaining the following: the integrity and effectiveness of the capping system; the groundwater monitoring system, and the surface water management system.	R/A
B. Delaware Hazardous Waste Management Regulations (DNREC Regulations Governing Hazardous Waste [DRGHW])		
1. DRGHW Part 264 Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal		
a. Groundwater Protection (Subpart F)	Groundwater monitoring should be conducted in accordance with substantive monitoring criteria.	
264.91 – Required programs	Requires owners and operators to conduct groundwater monitoring and response program.	R/A
264.92 – Groundwater protection standard	Requires a groundwater protection standard be established in the facility permit when hazardous constituents have been detected in groundwater.	R/A
264.93 – Hazardous constituents	Requires the hazardous constituents that have been detected in groundwater in at least the uppermost aquifer underlying a regulated unit and that are reasonably expected to be in or derived from waste contained in a regulated unit to be identified in the facility permit.	R/A
264.94 – Concentration limits	Establishes the concentration limits in the groundwater for the hazardous constituents identified in 264.93.	R/A
264.95 – Point of compliance	Requires the point of compliance at which the groundwater protection standard applies and at which monitoring must be conducted.	R/A
264.97 – General groundwater monitoring requirements	Requires a groundwater monitoring system must contain a sufficient number of wells, installed at reasonable locations and depths. Requires the wells to be installed properly. Requires a groundwater monitoring program with consistent sampling and analysis procedures that will provide a reliable indication of groundwater quality below the waste management area.	R/A
264.98 – Detection monitoring program	Requires that the owner or operator establish a detection monitoring program, which shall include indicator parameters, waste constituents, or reaction products that provide a reliable indication of the presence of hazardous constituents in groundwater.	R/A
264.101 – Corrective action for solid waste management units	Requires corrective action to protect human health and the environment for all releases of hazardous waste or constituents from any solid waste management unit at the facility, regardless of the time at which waste was placed in the unit.	R/A
C. Delaware Water Pollution Control Acts		
1. State of Delaware Regulations Governing Underground Injection Control (DRGUIC parts 122 and 146.)	Substrate will be injected into groundwater to promote biodegradation of contaminants.	
122.3 -- Definitions	Defines terms used in these regulations.	A

(1) A = Applicable R/A = Relevant and Appropriate

Table 2b. State ARARs (cont'd)

Environmental Laws and Regulations	Consideration as an ARAR	Status (1)
122.7 – Conditions applicable to all permits	Well construction, operation and maintenance, and abandonment should comply with the substantive requirements of this section.	A
122.11 – Requirements for recording and reporting of monitoring results	Comply with substantive requirements for collection and maintenance of monitoring results.	A
122.22 – Classification of injection wells	Wells used for injection are Class V wells.	A
122.24 – Prohibition of movement of fluid into USDWs	Injection of fluid may not cause a violation of any primary drinking water regulation.	A
122.32 – Establishing UIC permit conditions	Well construction, operation and maintenance, and abandonment should comply with the substantive requirements of this section.	A
146.06 – Area of review	Requirement to calculate the area impacted by the injection.	A
146.08 – Mechanical integrity	Requirements for adequate well construction and maintenance.	A
D. Delaware Code Annotated, Title 7 – Conservation, (Chapter 40 Erosion and Sedimentation)		
1. Delaware Sediment & Stormwater Regulations	Activities resulting in the disturbance of soil will require measures to control erosion.	
2.0 -- Definitions	Defines terms used in these regulations.	A
10.0 – Specific design criteria and minimum standards and specifications	Management of erosion and stormwater runoff from earth-disturbing activities should comply with the substantive requirements of this section.	A
12.0 – Certified construction reviewer requirements	Requirement to provide construction review during land disturbing activity.	A
14.0 – Construction review and enforcement requirements	Requirement for pre- and post-completion inspections.	A
15.0 – Maintenance requirements	Required maintenance for adequate erosion and sediment control.	A
E. Delaware Regulations Governing the Construction and Use of Wells (1997)		
Section 2 -- Definitions	Defines terms used in these regulations.	A
Section 3 – General Requirements and Procedures	The substantive requirements of these regulations apply to the location, design, installation, use, modification, repair, and abandonment of wells and associated equipment.	
3.03 – License required	Well driller must be licensed by the State of Delaware.	A
3.13 – Water well contractor and well driller responsibilities	Contractor is responsible for construction of the well and for submitting well completion report.	A
3.14 – Property owner's responsibilities	Responsible for maintaining and repairing well, and properly abandoning well.	A
Section 4 – Well Construction Standards		
4.01 – Siting Criteria	Requirements for minimum distances between wells, from any well to the property line, and from any well to a source of contamination, as well as requirements as to the specific location of wells.	A
4.02 – Sanitary protection during well construction	Requirement to protect well during construction from any contamination, including surface water drainage.	A
4.03 – Water for well construction	Requirements as to the source of water used for various purposes in well construction.	A
4.04 – Well casing	Requirements as to the dimensions of and materials used for well casing to prevent	A

(1) A = Applicable R/A = Relevant and Appropriate

Table 2b. State ARARs (cont'd)

Environmental Laws and Regulations	Consideration as an ARAR	Status (1)
	contaminants for entering sources of drinking water.	
4.05 – Well screens	Requirement for well screens to limit the entrance of sediment into the well.	A
4.06 – Gravel packed wells	Requirements for cleaning gravel to be used in well construction.	A
4.07 – Well grouting	Requirements for grouting wells following construction.	A
4.08 – Well development	Requirements for priming wells to remove mud, drilling fluids, etc.	A
4.10 – Well caps and upper terminus of wells	Requirements for height of wells above ground surface, and capping of wells.	A
4.11 – Water level access ports and tubes	Requirement for wells with a pumping capacity greater than fifty thousand gallons per day to be constructed with a port and access tube.	A
4.12 – Meters, pumping equipment, and vents	Requirements for wells with a pumping capacity greater than fifty thousand gallons per day to be equipped with meters, pumping equipment and vents.	A
Section 5 – Special Construction Requirements		
5.01 – Monitor and observation well construction	Requirement for monitoring well construction to comply with standard well construction requirements in these regulations.	A
5.02 – Coastal well construction	Special construction standards apply to wells constructed in areas prone to wave action or flooding.	A
Section 7 – Well Completion Information	Sets forth information to be provided at completion of well construction.	A
Section 8 -- Well Maintenance and Repair	Requirements for materials and procedures to be used in well maintenance and repair.	A
Section 9 – Well Abandonment	Requirements procedures and materials to be used to properly abandon wells to prevent migration of contaminants into or between aquifers.	A
Section 10 – Well Identification Tag	Requirement to physically tag the well for identification after construction completion.	A

(1) A = Applicable R/A = Relevant and Appropriate