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INSTALLATION RESTORATION PROGRAM

RECORD OF DECISION
FOR NATURAL ATTENUATION OF GROUNDWATER AND NO FURTHER ACTION FOR SOIL AT LIQUID WASTE DISPOSAL AREA 14 (WP14) AND LANDFILL 15 (LF15), WITHIN THE EAST MANAGEMENT UNIT AT DOVER AIR FORCE BASE, DELAWARE

AUGUST 1997

Submitted to
436th Airlift Wing, CES/CEV
Dover Air Force Base, Delaware 19902-6600

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ACRONYMS

1,2-DCA	1,2-Dichloroethane
1,2-DCE	1,2-Dichloroethene
4,4'-DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene
ARARs	Applicable or relevant and appropriate requirements
AS	Air sparging
AWQC	Ambient Water Quality Criteria
bgs	Below ground surface
BRA	Baseline Risk Assessment
BTEX	Benzene, toluene, ethylbenzene, and xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
cfm	Cubic feet per minute
COC	Contaminant of concern
DAFB	Dover Air Force Base
DDC	Density-driven convection
DNREC	State of Delaware Department of Natural Resources and Environmental Control
EMU	East Management Unit
ER-L	Effects Range-Low
FS	Feasibility Study
ft.	Feet or foot
ft 2	Square feet
FT03	Fire Training Area 3
GAC	Granular activated carbon
gpm	Gallons per minute
HI	Hazard Index
IRP	Installation Restoration Program
lb	Pound
lbs/day	Pounds per day
LECR	Lifetime excess cancer risk
LF13	Landfill 13
LF15	Landfill 15
MCL	Maximum Contaminant Level
Ig/kg	Micrograms per kilogram
Ig/L	Micrograms per Liter
mg/kg	Milligrams per kilogram

NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	Operations and maintenance
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PP	Proposed Plan
psig	Pounds per square inch-gauge
RAO	Remedial action objective
RBC	Risk-based concentration
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act of 1986 and 1990
SDWA	Safe Drinking Water Act
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCE	Trichloroethene
TPH	Total petroleum hydrocarbon
USACE	U.S. Army Corp of Engineers
USAF	U.S. Air Force
USEPA	U.S. environmental Protection Agency
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WP14	Liquid Waste Disposal Area 14

1. DECLARATION OF THE SELECTED REMEDY

1.1 SITE NAME AND LOCATION

Liquid Waste Disposal Area 14 (WP14) and Landfill 15 (LF15), Area 1, East Management Unit (EMU), Dover Air Force Base (DAFB), Kent County, Delaware

1.2 STATEMENT OF BASIS AND PURPOSE

This record of decision (ROD) presents the selected remedial action for soil and groundwater at WP14/LF15 which was chosen in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations Part 300. The U.S. Air Force (USAF), the lead agency, as the owner/operator of the Base, prepared this decision based on the Administrative Record for the site. The U.S. Environmental Protection Agency (USEPA) Region III and the State of Delaware Department of Natural Resources and Environmental Control (DNREC) provided support.

The State of Delaware concurs with the selected remedy. The Information Repository for the Administrative Record contains the information supporting this remedial action decision and is at the Dover Public Library, Dover, Delaware.

1.3 ASSESSMENT OF THE SITE

Dover AFB identified soil and groundwater contamination related to the activities that occurred in and around the WP14/LF15 site. WP14 and LF15 are inclose proximity to one another and compose what is referred to as Area 1. WP14 is the location of a former liquid waste disposal trench located in the northeast portion of the Base. This trench was used in the 1950s for the disposal of waste solvents, hydraulic fluids, waste oils, and other liquid wastes generated in shop operations. No record exists whether or not this trench was lined. After disposal activities ended at this site, probably in the early 1960s, the trench was filled with 3 to 4 feet (ft.) of local soil and seeded with grass. Free product recovery was actively conducted at the site from 1994 to early 1996. WP14 has remained vacant since it was closed.

LF15 is the location of a former trenched landfill located next to WP14. The site was initially reported to cover an area of less than 0.5 acre; however, personnel familiar with the site described it as much larger. During the 1960s, LF15 was reportedly used for the disposal of general refuse and small quantities of industrial shop wastes. The disposal area was filled to a depth of approximately 8 ft.. When disposal activities ceased at an unknown date, the site was covered with several feet of local soil and seeded. LF15 is currently a grass-covered field.

Environmental investigations identified significant volatile organic compounds (VOCs) in groundwater at both sites including fuel-related floating product in a well near WP14 and metals above action levels in LF15 groundwater. VOCs were also noted in surface water samples collected for the LF15 study. Both fuel-related and chlorinated compounds were detected in groundwater, but the fuel-related compounds were determined to not be migrating away from the their source area. Chlorinated compounds, primarily 1,2-Dichloroethene (1,2-DCE), Tetrachloroethene (PCE), and Trichloroethene (TCE), originate from both sites and are present in all downgradient monitoring wells. The concentrations of these contaminants are not sufficiently elevated to indicate the presence of free phase product.

The findings from the soil sampling conducted during the remedial investigation (RI) (Draft Final RI Basewide Remedial Investigation, August 1995) showed the presence of chlorinated solvents, fuel-related VOCs, and semivolatile organic compounds (SVOCs) contaminants in soil, but their levels were generally below action levels and do not indicate a significant soil problem at this site. Except for arsenic, metal concentrations were below or slightly over background concentrations. Arsenic concentrations were detected above site background but below risk based screening levels (RBSQ in several soil samples collected in portions of the site called the tetraethyl lead disposal area and the primary disposal trench. The source of the arsenic appears to be related to disposal activities at LF15. Remaining soil contaminants do not appear to be a human health risk; therefore, no further action of the soil at WP14/LF15 is the selected remedy The sediments at WP14/LF15 may pose an ecological risk due to concentrations of metals detected. These sediments, and other related site conditions, are planned to be addressed in the final base-wide ROD.

A Baseline Risk Assessment (BRA) was conducted for WP14/LF15. The risks to exposure of WP14 and LF15 soils produce a lifetime excess cancer risk (LECR) less than 1E-06 and Hazard Index (HI) of less than 1 for both current and future commercial/industrial scenarios. The LECR and HI associated with the hypothetical future commercial/industrial use of groundwater are 9E-04 and 1, respectively. The HI is the criterion used to evaluate the noncarcinogenic effects. Because the LECR value is above the 1E-04 to 1E-06 range, it is appropriate to consider risk-reducing action for groundwater at this site. No action is acceptable for soil due to low risk. The carcinogenic risk at WP14/LF15 is primarily attributable to vinyl chloride in groundwater and arsenic in both soil and groundwater.

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

1.4 DESCRIPTION OF THE SELECTED REMEDY

The selected remedy consists of in situ Remediation of groundwater using natural attenuation, institutional controls consisting of continuation of the restrictions on using on-Base groundwater and performance of groundwater monitoring. Final evaluation of the performance of this interim remedy, Remediation of contaminated groundwater at the site, and compliance with applicable or relevant and appropriate requirements (ARARs) will occur in the final Basewide ROD.

1.5 STATUTORY DETERMINATIONS

The selected remedial action satisfies the remedial selection process requirements of CERCLA and NCP. As required under CERCLA, the selected remedy provides the best balance of trade-offs among the nine evaluation criteria. The selected action provides protection of human health and the environment, complies with federal and state requirements that are legally applicable or relevant and appropriate to the action, and is cost effective. This remedy uses permanent solutions and alternative treatment technology to the maximum extent practicable and satisfies the statutory preference for remedies that use treatments that reduce toxicity, mobility, or volume as a principal element.

Because the remedy will result in the continued presence of hazardous substances on the site above action levels, a review will be conducted within 5 years of commencement of the remedial action to ensure the remedy continues to provide adequate protection of human health and the environment in accordance with NCP Section 300.430 (f)(4)(ii). This 5-year review will be performed as part of a Basewide monitoring program.

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2.1 INTRODUCTION

DAFB recently completed a draft Feasibility Study (FS) and a technical assessment of natural attenuation processes at DAFB that addressed contaminated soil and groundwater in the immediate vicinity of WP14/LF15. The two sites comprise what is called Area 1 and are located along the eastern boundary of DAFB. The sites are combined because of their close proximity and similar contaminants.

The Draft Feasibility Study, East Management Unit, Dover Air Force Base (Dames & Moore May 1997) was undertaken as part of the U.S. Air Force's Installation Restoration Program (IRP). The basis for the FS was the Draft Final Basewide Remedial Investigation, East and North Management Units, Dover Air Force Base report (Dames & Moore August 1995), which characterized contamination and evaluated potential risks to public health and the environment. This document was supplemented by two administrative reports titled Hydrogeologic and Water-Quality Data for the East Management Unit of Dover Air Force Base, 1995-96 and Assessment of Natural Attenuation of Contamination from Three Source Areas in the East Management Unit, Dover Air Force Base, both prepared by the U.S. Geological Survey (USGS), Baltimore, Maryland, in February and March 1997, respectively.

Early environmental investigations identified significant VOCs in groundwater at both sites including fuel-related, chlorinated compounds, and metals in LF15 groundwater. Floating product was found in a well near WP14. VOCs were also noted in surface water samples collected for the LF15 study. The fuel-related compounds (i.e., benzene, toluene, ethylbenzene, xylene (BTEX)] do not appear to be migrating away from the source areas because of the absence of the compounds in the downgradient wells. Chlorinated compounds, primarily 1,2-DCE, PCE, and TCE, originate from both sites and are present in all downgradient monitoring wells. Most of the chlorinated contaminants exceeded their respective Maximum Contaminant Levels (MCLs); however, the concentrations of these contaminants are not sufficiently elevated to indicate the presence of free phase product.

The investigations detected mainly fuel-related VOCs in soils. While still below the risk-based screening concentration (RBSC), the only significant concentrations of VOCs detected were ethylbenzene and xylenes, which were associated with one of the test pits at LF15. Other VOCs were also detected at lower concentrations. SVOCs and pesticides were detected below action, levels at a few locations. The SVOCs were predominantly fuel-related Polycyclic aromatic hydrocarbons (PAHs) associated with disposed material and jet engine exhaust. The pesticides detected maybe site related; however, the long-term use of pesticides by the surrounding farms and the base is a more likely source. A few metals, especially arsenic, exceeded background concentrations, but were not pervasive across the site. Arsenic concentrations were above background levels but below their RBSC in several soil samples collected in a portion of the site called the tetraethyl lead disposal area. The source of the arsenic appears to be related to disposal activities at LF15.

Site related VOCs were detected in the surface water samples from Pipe Elm Branch. These contaminants volatilized quickly and were not detected in off-base samples. Several metals were slightly elevated in sediment samples.

This ROD addresses the potentially hazardous substances present in WP14/LF15 soil and groundwater. This ROD summarizes the FS, describes the remedial ALTERNATIVES that were evaluated, identifies the remedial alterative selected by DAFB, and explains the reasons for this selection. The State of Delaware concurs with the remedy selected in this ROD.

As an aid to the reader, a glossary of the technical terms used in this ROD is provided at the end of the summary.

2.2 PUBLIC PARTICIPATION

DAFB offered opportunities for public input and community participation during the RI/FS and Proposed Plan (PP) for WP14/LF15 in the EMU. The PP was made available to the public in the Administrative Record. Documents composing the Information Repository for the Administrative Record for the site are available at the Dover Public Library, Dover, Delaware. The notice of availability for the PP was published in the local newspaper and the base newspaper. A public comment period was held from Monday, June 16, 1997, until Wednesday, July 15, 1997. The public comment period was not extended as there were no requests for an extension. No written comments were received from the public, and no public meeting was requested. These community participation activities fulfill the requirements of Section 113(k)(2)(B)(i-v) and 117(a)(2) of CERCLA.

Comments submitted by the USEPA and DNREC consisted of editorial changes and clarification of some issues; however, the editing and clarification did not result in any significant change to the preferred alternative presented in the PP.

2.3 SITE BACKGROUND

DAFB is located in Kent County, Delaware, 3.5 miles southeast of the city of Dover (Figure 1) and is bounded on the southwest by the St. Jones River. DAFB comprises approximately 4,000 acres of land, including annexes, easements, and leased property (Figure 2). DAFB is relatively flat, with elevations ranging from approximately 10 to 30 ft. above mean sea level. The surrounding area is primarily cropland and wetlands.

DAFB began operation in December 1941. Since then, various military services have operated out of DAFB. The current host organization is the 436th Airlift Wing. Its mission is to provide global airlift capability, including transport of cargo, troops, equipment, and relief supplies.

DAFB is the U.S. East Coast home terminal for the C-5 Galaxy aircraft. The base also serves as the joint services port mortuary, designed to accept casualties in the event of war. The C-5 Galaxy, a cargo transport plane, is the largest aircraft in the USAF, and DAFB is one of the few military bases at which hangars and runways are designed to accommodate these planes.

The portion of DAFB addressed in this RODCIRP Site WP14/LF15 Cis located within the EMU, one of four management units into which the base has been divided (Figure 2). WP14/LF15 are in close proximity to each other and are collectively known as Area 1

WP14 is the site of a liquid waste disposal area. Waste activities occurred at three potential areas; a tetraethyl lead disposal area, the primary trench, and a liquid-stained area. WP14 is located in the northeast portion of DAFB, east of the N/S runway, near the access road leading to the Receiver Station and Reno Road. It is situated approximately 500 ft. to the east of the hammerhead taxiway which is a hazardous cargo loading zone. The trench at WP14 was initially delineated in 1983 by a heavy equipment operator who was involved in its construction.
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He stated that the trench was 15 ft. wide, 100 ft. long, and 6 ft. deep. The former liquid waste disposal trench was used in the 1950s for the disposal of waste solvents, hydraulic fluids, waste oils, and other liquid wastes generated in shop operations. No record exists whether or not this trench was lined. After disposal activities ended at this site, probably in the early 1960s, the trench was filled with 3 to 4 ft. of local soil and seeded with grass. Free product recovery was actively conducted at the site from 1994 to early 1996. WP14 has remained vacant since it was closed.

LF15 is the location of a former trenched landfill located 200 ft. east of WP14. The site was initially reported to cover an area of less than 0.5 acre; however, the site is currently described as encompassing an area of 2 acres. During the 1960s, LF15 was reportedly used for the disposal of general refuse and small quantities of industrial shop wastes. The disposal area was filled to a depth of approximately 8 ft. When disposal activities ceased at an unknown date, the site was covered with several feet of local soil and seeded. LF15 is currently a grass-covered field.

The area is mainly flat with gentle undulations, and is located in a maintained grass-turf area that is likely used by grazers and insect-hunting birds. Surface water runoff flows overland to the north-northwest, where it is collected by a drainage ditch and ultimately discharges to the Pipe Elm Branch of Little River.

The Columbia Formation is the shallowest water-bearing unit and holds the water table aquifer. Deeper aquifers are protected by the extensive upper clay of the Calvert Formation. The upper portion of the Columbia Formation is finer grained and contains more silt and clay lenses than the deeper portions. The deeper portion of the Columbia Formation typically consists of fine-to-coarse-grained sand with occasional lenses of fine-to-medium sand and discontinuous gravel lenses interpreted as channel lag deposits. The thickness of the Columbia Formation at WP14/LF15 is approximately 50 ft. According to the USGS (May 1997), WP14/LF15 appears to be located in a recharge area for both the shallow and deeper flow systems. The shallow system discharges to the drainage ditch and the deeper system discharges to Pipe Elm Branch. The water table is generally encountered at a depth of 10 to 15 ft. below ground surface (bgs) at WP14/LF15.

Other structures near WP14/LF15 include an inactive JP-4 fuel pipeline approximately 350 ft. upgradient (south) of the area.

WP14/LF15 has undergone several previous investigations, three conducted by Science Applications international Corporation (1984, 1986, and 1990) and one, the RI conducted by Dames & Moore (1995).

2.3.1 Previous Investigations at WP14

The 1986 investigation of WP14 identified VOCs, oil and grease, lead, total organic halogens, and total organic carbon as site contaminants. The data indicated that WP14 may be the source of high (above action requirements) levels of VOCs in groundwater; however, there was insufficient information to discern WP14-related contamination versus nearby sites or background conditions.

The second investigation included an extensive soil gas sampling effort, a magnetometer survey, and soil and groundwater sampling. The soil gas results indicated the presence of high concentrations of volatile compounds in the center of WP14. The elevated levels of methane at the center of the site were interpreted as the decomposition of subsurface organic material in the vicinity of the trench. The magnetometer survey defined the trench as approximately 20 ft. wide by 45 ft. long and oriented northeast by southwest. The previous site description was larger, suggesting that the magnetometer survey identified only where metal objects reside in the trench.

Soil data revealed VOCs, SVOCs, and nine metals at concentrations of concern, but below action levels or background concentrations. In groundwater, PCE was present directly downgradient of WPl4. The presence of floating product in MW13, which is closest to the suspected trench, suggests that subsurface soil around the trench may be a source of contaminants in groundwater. In general, groundwater data indicated that VOCs were present in the upper portion of the Columbia Aquifer around WP14 and extending downgradient toward the drainage ditch. Organic compounds were not present at high concentrations in any of the deep groundwater samples in this area.

The data from the sediment and surface water sampling indicated that chlorinated solvents (e.g., TCE), and potentially, other VOCs and metals, may have migrated in groundwater from WP14 to Pipe Elm Branch, but concentrations are below action levels or background concentrations. Also, the data would suggest an attenuation of the compounds in groundwater through natural processes before reaching the discharge point at the drainage ditch.

2.3.2 Previous Investigations at LF15

The 1984 investigation of LF15 identified VOCs and metals in groundwater. The data was insufficient to evaluate whether LF15 or nearby Site WP14 was the source of organic contaminants. LF15 was identified as a possible source for chromium and nickel concentrations above action levels in groundwater.

The next investigation included an extensive soil gas sampling effort, geophysical surveys using electromagnetic conductivity, magnetic, and ground penetrating radar, and soil and groundwater sampling. The soil gas results indicated the presence of chlorinated compounds in the western portion (filled area) of LF15. The geophysical surveys identified several anomalies, the first was interpreted as a 0.5 to 0.75-acre fill area containing metal and debris in the western portion of the site. A second anomaly, east of the fill area, was interpreted as a potential buried trench.

During the 1989 investigation, LF15 was identified as a probable source for VOC contamination of groundwater. Metals and inorganics did not appear to be significantly above action levels or background concentrations at this site in groundwater. Toluene, chlorinated solvents, and metals were detected in surface water samples, and total petroleum hydrocarbons (TPH) and metals were present in sediment. The report concluded that the LF15 and WP14 were the sources of these contaminants, and that they may migrate in groundwater and discharge to the stream channel.

The third investigation focused primarily on WP14, but additional soil gas and groundwater samples were collected. Solvent-related VOCs were detected downgradient of the western portion of the site, metals were detected at shallow and deep wells throughout the site. The report concluded that VOCs from LF15 were present in the top of the Columbia Aquifer. Several metals (e.g., chromium and mercury) were reportedly above background concentrations, but attributed to another nearby site [Landfill 13 (LF13)]. Sediment and surface wafer samples collected from Pipe Elm Branch detected no site-related organic contaminants. Metals appeared to be a possible concern in surface water, but not no sediment. The report concluded that there was no significant migration of WP14/LF15 contaminants to or through Pipe Elm Branch.

2.3.3 Previous Investigations at Both WP14/LF15

The RI, conducted from February 1993 to May 1994, showed that WP14 and LF15 appear to be the sources of organics in the groundwater. Although the investigations detected chlorinated solvents and fuel-related VOCs and SVOCs in the soil, their concentrations are below RBSCs and do not indicate a soil problem at this site. Organic contaminants detected in samples include SVOCs at 77 Ig/kg or less, pesticides at 11 Ig/kg or less, and TPH at 31 Ig/kg or less. Several pesticides were detected below action levels in surface soil samples, with concentrations decreasing with depth. These contaminants do not appear to be related to WP14/LF15, but rather to the widespread use of these pesticides across the base. Except for arsenic, metal concentrations were below or only slightly over background concentrations. Arsenic concentrations were above background concentrations in several soil samples collected in a portion of the site called the tetraethyl lead disposal area and the primary disposal trench. The source of the arsenic may be related to the disposal activities at the site.

The fuel-related compounds (i.e., BTEX) are not migrating away from their source area as evidenced by the absence of the compounds in the downgradient wells. Chlorinated compounds, primarily 1,2-DCE, PCE, and TCE, originate from both sites and are present in all downgradient monitoring wells. Most of the chlorinated compounds exceeded their respective MCLs; however, the concentrations of these contaminants are not sufficiently elevated to indicate the presence of free-phase product.

Pesticides and Polychlorinated biphenyls (PCBs) were detected in soil and groundwater at the site; however, their concentrations were generally at concentrations below their action levels for commercial/ industrial soil ingestion and MCLs for water. Aroclor 1260 was detected in several soil samples at low concentrations, but not above its action level. Dieldrin (a pesticide) was detected in two surface soil samples above its action level for commercial/ industrial soil ingestion; however, it and other pesticides in soil and groundwater are generally attributed to manufacturer-specified long-term application of these compounds across the base and surrounding farmlands.

Approximately 36 soil borings and 38 monitoring wells have been installed during the investigation of WP14 and 6 soil borings and 15 monitoring wells for LF15. Figures 3 and 4 illustrate the WP14 and LF15 site areas and sampling locations, respectively. The estimated sizes of the WP14 and LF15 source areas are 8,800 square feet (ft 2) and 13,000 ft. 2 respectively.

2.4 SUMMARY OF SITE RISKS

The purpose of the BRA (Draft Final RI Report, August 1995) is to determine whether exposure to site-related contaminants could adversely affect human health. The focus of the BRA is on the possible human health effects that could occur under current or potential future use conditions if the contamination is not remediated. The risk is expressed as LECR for carcinogens and as HI for noncarcinogens. For example, an LECR of 1E-06 represents one additional case of cancer in one million exposed population, whereas an HI above one presents a likelihood of noncarcinogenic health effects in exposed populations. The USEPA has established the target risk range of 1E-04 to 1E-06 for LECR. Risks greater than 1E-04 generally warrant an action under CERCLA. An HI greater than 1 indicates a possibility of adverse noncancer health effects based on exposure to multiple contaminants or pathways. The uncertainty with noncancerous health toxicity values is a factor of 10, so HI values greater than 1 may not necessarily require an action under CERCLA in order to be protective of human health. It Is considered very unlikely that the Columbia Aquifer would be used by the base. To ensure the Columbia Aquifer would not be used, institutional controls for restrictions of the groundwater use at WP14, LF15 would be implemented as part of the selected alterative. The restriction would be applicable to all scenarios of groundwater use including residential, recreational, and commercial/industrial.

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The RI/FS focused on the collection of data to determine extent of contamination in the vicinity of WP14/LF15. The BRA identified several contaminants of concern (COCs) in soils at WP14:

SVOCs:	2-Methylnaphthalene	Metals:	Arsenic
	Benzo[g,h,i]perylene		Beryllium
	Dibenzofuran		Calcium
	Phenanthrene		Cobalt

Pesticides: Delta-benzene hexachloride
Dieldrin
Endosulfan II
Endosulfan sulfate
Endrin ketone

A summary of the major contaminants and their concentrations detected in soil samples from WP14 during the RI is given in Table 1. The BRA, performed as part of the Basewide RI, considered hypothetical current and future soil use under the commercial/industrial scenario. Details concerning the selection of COCs and the human health risks may be reviewed in the Draft Final RI. Volumes III and IV, August 1995.

The total LECRs for the hypothetical current and future commercial/industrial exposure to soil is 2E-07 and 4E-06, respectively. Arsenic is the primary contributor to the LECR. The resulting risk exposures are given in Table 2.

Soil COCs identified at LF15 are:

SVOCs:	2-Methylnaphthalene	Metals:	Arsenic
	Dibenzofuran		Calcium
	Phenanthrene		Cobalt
			Magnesium

Pesticides: Delta-benzene hexachloride

Table 1. Summary of Major Contaminant Detected During the RI in WP14 Soil

Analyte	Highest concentration (Ig/kg)	Number of hits	Number of samples	Background conc. (Ig/kg)
Volatile organic compounds				
Chloroform	2.0	2	38	940,000*
Toluene	3	2	38	4.1E+08*
Xylene (Total)	2	1	38	IE+09*
Semivolatile organic compounds				
2-Methylnaphthalene	2100	2	17	
Bis(2-ethylhexyl)phthalate	210	4	17	410,000*
Naphthalene	1900	1	17	8.2E+07*
Pentachlorophenol	100	1	17	48,000*
Phenanthrene	920	2	17	
Pesticides/PCBs				
4,4'-DDE	4700	11	17	17,000*
Metals	(mg/kg)			(mg/kg)
Aluminum	37,900	38	38	23,855
Arsenic	71.7	29	38	19.8
Beryllium	1.8	5	38	1.7
Calcium	2490	38	38	1080
Cobalt	8.9	29	39	6
Copper	12.1	26	33	7.8
Lead	85.6	37	38	33.1
Mercury	0.25	11	38	0.16

* USEPA Risk-Based Concentrations for Commercial/Industrial soil ingestion scenario.

Table 2a. Hypothetical Current Commercial/Industrial Scenario for Soil at WP14

Pathway	Hazard Index	LECR
Ingestion	1E-03	2E-07
Inhalation	NA	1E-10
Total	1E-03	2E-07

NA = Not Applicable.

Table 2b. Hypothetical Future Commercial/Industrial Scenario for Soil at WP14

Pathway	Hazard Index	LECR
Ingestion	2E-01	4E-06
Inhalation	NA	1E-08
Total	2E-01	4E-06

NA = Not Applicable.

A summary of the major contaminants and their concentrations detected in soil samples from LF15 during the RI is given in Table 3. The BRA, performed as part of the Basewide RI, considered hypothetical current and future soil use under the commercial/industrial scenario. Details concerning the selection of COCs and the human health risks may be reviewed in the Draft Final RI, Volumes III and IV, August 1995.

The total LECRs for the hypothetical current and future commercial/industrial exposure to soil is 1E-07 and 2E-06 respectively. Arsenic is the primary contributor to the LECR. The resulting risk exposures are given in Table 4.

Area 1 groundwater contained several COCs:

Vocs:		Pesticides:
1,1,2,2-tetrachloroethane		Delta-benzene hexachloride
1,2-DCA		Endosulfan II
1,1-DCE		Endosulfan sulfate
1,2-DCE		Endrin aldehyde
2-Hexanone		Endrin ketone
Benzene		Heptachlor
Ethylbenzene		Heptachlor epoxide
PCE		
TCE		
Vinyl chloride		

Table 3. Summary of Major Contaminants Detected During the RI in LF15 Soil

Analyte	Highest concentration (Ig/kg)	Number of hits	Number of samples	Background conc. (Ig/kg)
Volatile organic compounds				
Ethylbenzene	2000	2	16	2E+O8*
Xylene (Total)	9600	2	16	1E-09*
Semivolatile organic compounds				
2-Methylnaphthalene	590	1	10	
Bis(2-ethylhexyl)phthalate	87	3	10	410,000*
Naphthalene	1300	1	10	8.2E+07*
Metals	(mg/kg)			(mg/kg)
Aluminum	40,300	16	16	23,855
Arsenic	39.2	11	16	19.8
Cadmium	1.3	1	16	0.84
Calcium	20,200	16	16	1080
Cobalt	16	10	16	6
Copper	10.2	10	16	7.8
Lead	139	16	16	33.1
Magnesium	12,000	16	16	10,166
Mercury	0.23	9	16	0.16
Nickel	22.7	8	16	15

* USEPA Risk-Based Concentrations for Commercial/Industrial soil ingestion scenario.

Table 4a. Hypothetical Current Commercial/Industrial Scenario for Soil at LF15

Pathway	Hazard Index	LECR
Ingestion	5E-04	1E-07
Inhalation	NA	8E-11
Total	5E-04	1E-07

NA = Not Applicable.

Table 4b. Hypothetical Future Commercial/Industrial Scenario for Soil at LF15

Pathway	Hazard Index	LECR
Ingestion	1E-01	2E-06
Inhalation	NA	7E-09
Total	1E-01	2E-06

NA = Not Applicable.

SVOCS:	2-Methylnaphthalene	Metals:	Arsenic
	Bis(2-ethylhexyl)phthalate		Beryllium
	Phenanthrene		Cobalt

A summary of the major contaminants and their concentrations detected in Area 1 groundwater samples is given in Table 5. The detected concentrations of 13 contaminants in groundwater exceeded their respective MCLs in at least one of the samples collected during the RI in the vicinity of the source area. The source area for groundwater contamination is in close proximity to the base boundary and the groundwater discharge point is to a drainage ditch connected to Pipe Elm Branch of Little River, hence the potential exists for the future off-base migration of contaminants with groundwater.

The BRA, performed as part of the Basewide RI, considered hypothetical future groundwater use from the Columbia Aquifer under the commercial/industrial scenario. Details concerning the selection of the COCs and the human health risks may be reviewed in the Draft Final RI. Volumes III and IV, August 1995.

The total LECRs for the hypothetical future commercial/industrial exposure to groundwater is 1E-04. Vinyl chloride and arsenic are the primary contributors to the LECR. The resulting risk exposures are presented in Table 6.

Table 5. Summary of Major Contaminants Detected During the RI in WP14/LF15 (Area 1) Groundwater

Analyte	Highest concentration (Ig/L)	Number of hits	Number of samples	Maximum contaminant levels (Ig/L)
Volatile organic compounds				
1,2-Dichloroethane	74	4	39	5
1,2-Dichloroethene	130	14	39	70
Benzene	22.0	3	39	5
Methylene Chloride	33.0	2	39	5
Tetrachloroethene	890	10	39	5
Trichloroethene	260	13	39	5
Vinyl Chloride	59.0	1	39	2
Semivolatile organic compounds				
Bis(2-ethylhexyl)phthalate	350	1	15	6
Metals	(mg/kg)			(mg/kg)
Antimony	80.9	1	24	6
Arsenic	36.3	13	24	50
Beryllium	15.5	20	24	4
Chromium	249	21	24	100
Lead	101	18	24	15
Magnesium	31,000	24	24	
Manganese	4280	22	24	
Nickel	187	14	24	100

Table 6. Hypothetical Future Commercial/Industrial Scenario for Groundwater at Area 1

Pathway	Hazard Index	LECR
Ingestion	3E-01	9E-05
Inhalation	5E-02	2E-05
Total	4E-01	1E-04

2.5 REMEDIAL ACTION OBJECTIVE

Remedial action objectives (RAOs) are media-specific goals to be reached during site remediation that are protective of human health. hese objectives are typically achieved by preventing exposure and reducing contaminant levels (Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, USEPA, October 1988). The RAO for WP14/LF15 is the reduction of contaminant concentrations in soil to the USEPA Region III Risk-Based Concentrations (RBCs) for the commercial/industrial ingestion scenario. The RAO for groundwater is the Safe Drinking Water Act (SDWA) MCLs or Delaware's DNREC regulatory levels. The selected acceptable contaminant levels in groundwater are MCLs. For COCs that do not have a RBC or an MCL, the base-specific background level will be used. The area to be remediated is defined as the area of attainment. The area of attainment defines the area over which cleanup levels will be achieved in the groundwater. It encompasses the area outside the boundary of any waste remaining in place and up to the boundary of the contaminant plume. Cleanup levels are to be achieved throughout the area of attainment. Within the area of attainment, the goal of the remedial action for soil and groundwater is to reduce the concentrations of the COCs below their remedial action levels.

Groundwater-use is controlled by the existing DAFB water-supply program. Within the boundaries of the base, DAFB does not use the Columbia Aquifer for two primary reasons: 1) the aquifer cannot meet the base's residential and industrial demands and (2) the water quality of the Columbia Aquifer is less desirable than that of the deeper aquifer. Land-use restrictions will remain in place because DAFB is one of the few airports capable of servicing the C-5 Galaxy aircraft and it very likely will remain a USAF base in the distant future. These institutional controls help minimize exposure to site contaminants.

The potential exposure routes for WP14/LF15 contaminants are ingestion/inhalation of soil particles that have sorbed contaminants and contact and ingestion of contaminants in groundwater/surface water. The potential off-base migration of groundwater contaminants to areas not under DAFB land-use restrictions is another route of exposure. In this case, the objective is to prevent unacceptable levels of contaminants from migrating off-base by achieving the RAO within the area of attainment.

The selected acceptable contaminant levels are base-specific background concentrations for soil and MCLs for groundwater, which are available for most of the COCs at WP14/LF15. The primary contributor to the total LECR in soil is arsenic, which the DAFB-specific background concentration is 1.70 mg/kg. In groundwater vinyl chloride and arsenic are the primary contributors to the total LECR. The MCLs for vinyl chloride and arsenic are 2 Ig/L and 50 Ig/L respectively.

2.6 SUMMARY OF ALTERNATIVES

General response actions are the steps that could be taken to achieve the RAOs for the soil and groundwater at WP14/LF15. Based on results of the initial screening of the response action technologies presented in the FS and the selection of representative process options, the following six technologies are considered to be applicable:

- No Action
- Institutional Controls
  - Land-use restrictions
  - Groundwater-use restrictions
  - Groundwater monitoring

- In situ Groundwater Treatment
  - Natural attenuation
  - Density-driven convection
  - Permeable reactive barrier wall

- Groundwater Collection
  - Vertical groundwater extraction wells

- Ex situ Groundwater Treatment
  - Metals pretreatment
  - Air stripping

- Groundwater Disposal
  - Surface water discharge

These technologies are combined to form five distinct alternatives that have varying degrees of success at achieving the RAOs for WP14/LF15. The five alternatives and features of each technology are summarized as follows.

- Alternative 1--No Action. This alternative involves no activities to reduce contamination or to monitor site conditions. Institutional controls (e.g., restriction of groundwater use by DAFB) are already in place and are likely to remain so in the future. These controls, however, do not apply beyond the base boundary.

- Alternative 2--In Situ Remediation of Soil and Groundwater Using Natural Attenuation. This alterative relies on passive treatment of contaminated soil and groundwater through natural physical, chemical, and biochemical processes. These processes, particularly biodegradation processes, result in the reduction of soil and groundwater contaminant concentrations at reasonably predicted rates. Institutional controls consisting of continuation of the restrictions on using on-base groundwater and performance of groundwater monitoring are also included.

- Alternative 3--In Situ Remediation of Groundwater Using Density-Driven Convection. Density-driven convection is an in situ groundwater treatment technology that specifically addresses source area contamination. Soil contamination is addressed by use of soil vapor extraction technology. The distal end of the plume is addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using on-base groundwater and performance of groundwater monitoring are also included.

- Alternative 4--In Situ Remediation of Groundwater Using Permeable Reactive Barrier Walls. Groundwater in the source area is treated in situ using a Permeable wall of reactive iron filings. The distal end of the plume and soil are addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using on-base groundwater and performance of groundwater monitoring are also included.

- Alternative 5--Ex Situ remediation of Groundwater Using Air Stripping. Groundwater is removed from the source areas using extraction wells. The extracted water undergoes metals pretreatment and is then processed through an air stripper. The treated water is subsequently discharged to an on-base strewn: ipe Elm Branch. The distal end of the plume and soil are addressed by natural attenuation. Institutional controls consisting of continuation of the restrictions on using on-base groundwater and performance of groundwater monitoring are also included.

These remedial alternatives are described in the following subsections. In addition, the capital, annual operation and maintenance (O&M), and present worth costs of each alternative are provided.

2.6.1 Alternative 1--No Action

Alternative 1, the No Action alternative, is considered in the range of alternatives to serve as a baseline or to address sites that do not require active remediation. The NCP and CERCLA guidance require that the No Action alternative be evaluated. This alternative assumes that no remedial action will occur and that the site would be left in its present condition. No efforts are undertaken to reduce soil and groundwater contaminants. Any changes to the site would be a direct result of natural processes, and no monitoring would be conducted to document changes in contaminant levels.

Alternative 1

Cost Category	Cost ($)
Capital	0
Annual Operations and Maintenance	0
Present Worth	0

Existing land-use restriction in place at DAFB will continue to be enforced to prohibit the unauthorized extraction and use of groundwater from the Columbia Aquifer. This action will prevent human exposure to the groundwater, thereby averting a public health risk at DAFB. This alternative does not comply with the chemical-specific ARARs of the base-specific background concentrations for soil and SDWA MCLs for groundwater (See Table 9). The success of meeting the RAOs must be determined. No cost is associated with this alternative.

2.6.2 Alternative 2-In Situ Remediation of Soil and Groundwater Using Natural Attenuation

Alternative 2, in situ remediation of soil and groundwater using natural attenuation, relies on passive treatment of contaminated soil and groundwater through natural physical, chemical, and biochemical processes. USGS conducted an extensive natural attenuation study of the EMU sites (USGS, 1997) and concluded that none of the COCs were currently migrating past the base boundary above MCL concentrations in either groundwater or surface water. In addition, the COCs are not predicted to migrate off-base in the future. Nonetheless, groundwater monitoring will be employed to demonstrate that natural attenuation is effectively reducing contaminant concentrations and preventing their off-base migration at levels above the RAO concentrations over the long term. Natural attenuation processes, particularly biodegradation processes, result in the reduction of soil and groundwater contaminant concentrations at reasonably predicted rates.

Based on the aquifer characteristics and findings from the RI Report and the Natural Attenuation Study, the USGS reasoned that most of the attenuation is the result of biodegradation. The estimated time needed for biodegradation of chlorinated aliphatic hydrocarbons (e.g., TCE, PCE, vinyl chloride, 1,2-DCE) to decrease concentrations by one order of magnitude ranges from 0.1 to 3.7 years; the time needed for biodegradation to decrease concentrations by two orders of magnitude ranges from approximately 0.3 to 7.4 years. Using the longest flow path from LF13 to Pipe Elm Branch, approximately 3000 ft. long, the groundwater travel times are somewhere between 8 and 180 years from recharge to discharge. Given theses conditions, the USGS then reasoned that biodegradation can decrease concentrations to near or below the detection level in the long flow path. In the short flow path. it was concluded that although biodegradation can decrease concentrations, it would only do so by an order of magnitude. A table is included at the end of the ROD which shows the comparison of remediation times for natural attenuation of groundwater versus the calculated groundwater travel times. The results showed that for short travel paths (i.e., 100 ft. at Fire Training Area 3 (FT03)] and high flow velocities (i.e., 376 ft./year), natural attenuation processes are insufficient to decrease concentrations by one order of magnitude. In a couple of cases, the intermediate flow path of 1500 ft. and a high flow velocity was not satisfactory to decrease concentrations of PCE and TCE by one order of magnitude. It should be noted that the initial concentration of a specific contaminant will dictate cause for concern that groundwater will discharge to a surface water body and pose a risk to human health or the environment. Potential concerns for WP14/LF15 are described in the following paragraphs.

For WP14/LF15, concentrations of 1,2-dichloroethane (1,2-DCA) (74 Ig/L) and PCE (890 Ig/L) in groundwater may be sufficiently high that natural attenuation could be ineffective to meet the remedial objective of 5 Ig/L each. This assumes the worst case of a flow path of 1500 ft. to a surface water body, a high flow velocity of 376 ft./year, and the highest contaminant concentrations detected in the RI. The estimated remediation time through the natural attenuation process of bio-remediation for WP15/LF15 groundwater ranges from 4 to 8 years for PCE and 200 to 500 years for 1,2-DCA. The 200 to 500 years bio-remediation restoration time frame for 1,2-DCA is unacceptable to EPA and DNREC. However, because of the relatively low levels of 1,2-DCA present at this site, it is expected that even under the worst case scenario, the 1,2-DCA will naturally attenuate to MCLs due to dilution within a relatively short period of time. It is assumed that soil remediation times would be comparable because similar degradation processes are also occurring.

The RI and Natural Attenuation Study showed that concentrations of aliphatic and aromatic hydrocarbons (i.e., fuel-related components) are greatest near the spill sites and least downgradient. No fuel-related hydrocarbons were detected in the surface water samples collected in 1995 and 1996. In general, the USGS concluded that redox conditions measured at the sites are favorable for biodegradation of these compounds. One could then hypothesize that fuel-related hydrocarbons are being successfully biodegraded prior to discharge to the surface water bodies.

The proposed monitoring network is illustrated in Figure 5 and consists of five groundwater wells. During the Remedial Design, the base will develop, with DNREIL and EPA review and approval, an "Operation and Maintenance" plan, which will detail the monitoring wells, sampling parameters, frequency and performance standards necessary to support the natural attenuation decision both prior to and after the issuance of the final base-wide ROD.

Alternative 2

Cost Category	Cost ($)
Capital	4,200
Annual Operations and Maintenance	8,400
Present Worth	40,000

This alternative is considered capable of complying with the chemical-specific (e.g., base-specific background concentrations and MCLs) and action-specific (e.g.,long-term monitoring) ARARs (See Table 9). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit use of the contaminated soil and aquifer will remain in place.

2.6.3 Alternative 3 In Situ Remediation Using Density-Driven Convection

This alternative includes the in situ treatment of groundwater using density-driven convection (DDC) over the source areas of contamination. The DDC process is a recently developed in situ method for removal of VOCs from the saturated zone. The DDC process involves injection of air into the bottom of a well screened at both the top and the bottom. The injected air bubbles rise upward in the well and create a turbulent frothing action inside of the wellbore. The rising air bubbles snip contaminants from the water and increase the dissolved oxygen content of the water. The rising bubbles create a frictional drag, which produces a positive hydraulic head (i.e., greater than static aquifer head) at the bottom of the well. Thus, the frictional drag acts as a groundwater pump sucking contaminated water from the surrounding aquifer through the bottom well screen and pushing the water through the wellbore and out of the top well screen. Aerated water discharged through the top well screen then infiltrates back down to the water table, while the discharged air bubbles travel through the vadose zone and are captured by soil vapor extraction (SVE) wells. The designed air injection pressures range from 12 to 16 pounds per square inch - gauge (psig) with an injection flow rate of 20 cubic feet per minute (cfm) for DDC wells.

The DDC wells are assumed to have a diameter of 8 in. and will be installed to the bottom of the Columbia Aquifer at an average depth of 45 ft. bgs. The DDC wells will have a dual well screen. The bottom screen will be 15 ft. long and anchored at the bottom of the well. The bottom screen will be connected to a 5-ft. section of well casing to which the upper screen will be connected. The upper screen will be 15 ft. long and will straddle the water table. The well packing of the two screened intervals will be separated by a bentonite seal. Before completion of the well, a Atee@ with a capped 3-foot horizontal extension will be installed 3 ft. below grade to facilitate air piping. The wells will be completed with a flush-mount manhole and concrete cap.

The DDC wells will be operated by injecting air into the wells with a blower or compressor. Based on the estimated number of DDC wells, one air compressor unit will be used at Area 1. The compressor station can service 4 to 15 DDC wells. For costing purposes, the air compressor is assumed to have a 5-horse power motor producing 36 cfm at 16 psig. The air compressor unit will have a control panel and will be located within a weatherproofed shed. The control panel will have pressure controls, flow rate indicators, and control valves for each sparging line.

The DDC system will operate in tandem with an SVE system to capture volatile contaminants stripped from the saturated zone. SVE wells are constructed of slotted screen pipe surrounded by gravel or sand pack; a vacuum-tight seal at the ground surface will prevent short circuiting of air. The SVE wells are connected to a vacuum pump by air-handling piping. The vacuum pump produces a lateral air flow through the soil that picks up and carries gaseous-phase contaminants that are located in the interstitial soil pore spaces of the vadose zone. An air/liquid separator is used to remove liquids before entering the vacuum blower. An offgas carbon adsorption treatment system is included to remove extracted VOCs before atmosphere discharge of the gas stream.

Based on the formation permeability and thickness, the vendor that offers this technology (Wasatch Environmental) estimated that the effective radius of influence for single DDC wells will be 50 ft.. This radius of influence was used to determine the location and the number of the wells that will be required to remediate the source areas. The radius of influence for an SVE well is estimated to be 45 ft. based on the air sparging (AS)/SVE treatability study conducted at WP21 in the West Management Unit [Extended Aquifer Air Sparging/Soil Vapor Extraction Treatability Study for Site SS59 (WP21), Dover Air Force Base, EA Engineering, Science and Technology, 1994]. SVE wells were spaced approximately 80 ft. apart allowing for some overlap and providing full coverage. Based on the spacing requirements, WP14/LF15 is estimated to need 5 DDC wells and 14 SVE wells.

Using the results of the air sparging/SVE treatability study at WP21, the extraction vacuum pressures and flow rates are assumed to be 50 to 70 in. water column pressure and 25 to 30 cfm, respectively. For WP14/LF15 SVE wells, an estimated 1 vapor extraction station will be used. The extraction station will receive and treat vapors from 14 SVE wells. The extraction station will consist of a knock-out pot, a vacuum pump, and a vapor phase carbon adsorption unit to treat VOC-contaminated vapors. The knock-out pot will be located between the extraction wells and the vacuum pump and will separate entrained water in the extracted gas stream. Water generated in each knock-out pot will be piped to a 55-gallon liquid phase carbon adsorption unit. Liquid phase granular activated carbon (GAC) treatment units will be used to reduce the level of the organics to levels that comply with discharge requirements (See Table 9). Following treatment, the treated water will be discharged into surface drainage that flows into Pipe Elm Branch.

Vapor from the knock-out pot will be treated in vapor-phase carbon adsorption units where organic contaminants will be removed. The air flow at each station will be split into two parallel streams, each of which will be treated using a 150-pound (lb) canister of GAC. For the one vapor extraction station, two carbon canisters will be required. Initially (i.e., the first year of operation), the carbon canisters will have to be replaced about every 6 months. Each extraction station will be located within a weatherproofed shed. During subsequent years of operation, the carbon consumption rate will be progressively less as the contaminant extraction rates decline.

The SVE system will require periodic monitoring. For costing purposes, 12 air samples are assumed to be collected and analyzed the first month during startup. The first month's samples will be collected both upstream and downstream of the vapor-phase GAC units weekly. Thereafter, one air sample/month will be collected to track the progress and efficiency of remediation. In addition, the emissions from the SVE station will be monitored semiannually to ensure that it is in compliance with standards (See Table 9).

A field pilot test of the DDC system will be necessary before final design of the remediation action. The study will be used for system design and modeling of contaminant removal rates. Selected test wells will be installed to evaluate field responses to applied air pressures, identify the locations of clay lenses, confirm the radius of influence of the vapor extraction wells, determine the radius of influence of the DDC wells, and determine optimum operating conditions. The system addresses the source area at the site. The distal ends of the plume will be allowed to attenuate naturally.

Groundwater monitoring will be performed to track the long-term progress and effectiveness of groundwater remediation and to monitor contaminant migration. One new monitoring well (POC2) will be installed at WP14/LF15. The new well, in addition to the 4 existing wells, will be used to monitor plume migration. Samples will be collected and analyzed from the 5 wells semiannually. All groundwater samples will be tested for all COCs. The actual frequency, duration, and analytical parameters may change, depending on the long-term results of sampling. For costing purposes, monitoring is assumed to occur for 5 years.

Alternative 3

Cost Category	Cost ($)
Capital	150,000
Annual Operations and Maintenance	20,000
Present Worth	210,000

This alterative is considered capable of complying with the chemical-specific (e.g., emissions, base-specific background concentrations, and MCLs) and action-specific (e.g., active land treatment and long-term monitoring) ARARs (See Table 9). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit use of the contaminated soil and aquifer will remain in place. This action will prevent human exposure to the contaminated soil and groundwater, thereby averting a public health risk.

2.6.4 Alternative 4 In Situ Remediation Using Permeable Reactive Barrier Walls

Alternative 4 is the in situ treatment of groundwater using permeable reactive barrier walls. For WP14/LF15, this alternative includes the construction of two 375-ft. long impermeable barriers and the installation of 500 cubic yards of reactive iron filings in a 75-ft. trench to capture and channel the contaminated plume through the reactive wall where the contaminants will be degraded. The capture was modeled using the two-dimensional groundwater model TWODAN.

The Basewide RI report indicates that the water table is located at a depth of approximately 10 to 12 ft. bgs in this portion of the site. Each of the impermeable barriers constructed at WP14/LF15 wi11 bekeyed into the top of the Calvert Formation (approximately 40 to 60 ft. bgs) for their entire length. The impermeable barriers will be installed using either displacement drilling or displacement trenching, whereby a cement slurry is used to hold open the trench/hole while excavation advances. The slurry is then displaced by pumping in the final cement/grout mixture.

The reactive metal walls will be installed using a one-pass trenching tool. The width and thickness of the permeable barrier wall will be determined based on the results of a treatability study. The treatability study will be performed to determine the residence time required of the contaminated groundwater within the reactive wall. The study will consist of bench-scale tests that will use samples of the contaminated groundwater and pass them over the reactive metal to measure the contaminant degradation and, thus, determine, residence time requirements. Based on the known groundwater velocity at the wall, the residence time will determine wall thickness.

Groundwater monitoring will be performed to track the long-term progress and effectiveness of the groundwater remediation systems. It is proposed that 1 additional well (POC2) will be installed at WP14/LF15. The new well, and 4 existing wells, will be used in the groundwater monitoring program. Samples will be collected and analyzed from the wells semiannually. The groundwater samples are assumed to be tested for all COCs. The actual frequency, duration, and analytical parameters may change, depending on the long-tem results of sampling. For estimating purposes, monitoring for 5 years is assumed.

This alternative is considered capable of complying with the chemical-specific (e.g., MCLs) and action-specific (e.g., active land treatment and long-term monitoring) ARARs (See Table 9). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit use of the contaminated soil and aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

Alternative 4

Cost Category	Cost ($)
Capital	1,200,000
Annual Operations and Maintenance	18,000
Present Worth	1,300,000

2.6.5 Alternative 5 Ex Situ Remediation Groundwater Using Air Stripping

This alternative includes groundwater extraction, pretreatment of groundwater for metals removal, air stripping treatment to remove chlorinated solvents and fuel contaminants, and surface water discharge of treated groundwater from WP14/LF15.

Groundwater extraction will be accomplished by using one new extraction well installed at the site. The extraction well location was selected to control and capture the areas of contaminated groundwater at the site. The extraction rate and capture area from the well was estimated using the two-dimensional groundwater model TWODAN.

An extraction well operating at 10 gallons per minute (gpm) will be required at WP14/LF15. The well will create a capture zone that will limit further migration of contaminants and prevent discharge to the Pipe Elm Branch.

The Basewide RI report indicates that the water table is located at a depth of approximately 10 to 12 ft. bgs, in the WP14/LF15 area. The RI/FS reports also indicate that the most significant contamination is found in the upper third of the Columbia Aquifer. Therefore, the extraction well at WP14/LF15 will be installed across the upper portion of the Columbia Aquifer and will he screened using slotted stainless steel casing from 10 ft. bgs (screen length of approximately 20 ft.)- 30 ft. bgs. The well will be 6 in. in diameter. The filter pack will extend a minimum of 1 ft. above the well screen. Above the filter pack, a minimum 2-ft. bentonite seal will be installed, and the well will be grouted to the surface using a bentonite grout.

Contaminated groundwater will be extracted using a 4-in. stainless steel electric submersible pump. Following extraction, the groundwater will be pumped through 2-in. Schedule 80 plastic piping to the treatment system. The piping will be buried below the frost line at a minimum depth of 3 ft.. An estimated 375 ft. of pipe will be required at WP14/LF15 to convey extracted water from the recovery well to the treatment system and from the treatment system to die closest surface water discharge point.

The groundwater treatment system includes an initial pretreatment stage to reduce the metals content. This stage is added to prevent iron and manganese fouling in the subsequent air stripping unit as well as to ensure compliance with the National Pollutant Discharge Elimination System discharge standards. Groundwater will be pumped on a continual basis to an equalization tank, where it will be dosed with potassium permanganate to oxidize iron and manganese to their insoluble forms followed by pH adjustment with sodium hydroxide. Next, a cationic polymer will be introduced into a rapid mix tank, where it will be mixed instantly into solution. Rapid mixing will be followed by slow mixing or flocculation. The clarification tank follows flocculation and provides for quiescent settling of the metal-polymer flocs. The flocs will settle and produce an aqueous sludge. Clarified groundwater wi11 be sent to subsequent treatment systems void of high concentrations of iron and manganese, which can interfere with operation of the system. A bench-scale treatability study (USACE, 1994) was conducted for groundwater at Site WP21 to determine the type and amount of chemicals required for the metals pretreatment process. The results of this study were used to estimate the chemical dosage required for metals pretreatment.

A sludge characterization test such as the Toxicity Characteristic Leachate Procedure test will have to be conducted to determine the teachability of the metals and thus the method and cost of disposal (See Table 9). For costing purposes, the sludge will be assumed to be nonhazardous. The sludge will be dewatered to reduce the volume requiring disposal.

After pretreatment for metals, groundwater will be pumped to the top of a low-profile, four-tray air stripper. The water will be uniformly distributed across each tray and brought into contact with air forced up from the bottom of the unit by a blower. The counter-current airflow through the stripper unit transfers VOCs dissolved in the groundwater to the air stream. The air stream containing the VOCs then exits through the top of the air stripper unit while the treated groundwater flows out through the bottom of the air stripper unit. The air stripper unit selected has a liquid throughput capacity of up to 20 gpm.

Based on the average VOC concentration of groundwater samples collected at the site, an appropriate extraction rate, and assuming complete removal during treatment, 0.104 lbs/day (pounds per day) of VOCs will be stripped from the groundwater at WP14/LF15. The air stream exiting the air stripper will not require treatment before release to the atmosphere because the total VOC discharge is less than 2.5 lbs/day. Air samples will be collected monthly to ensure continued compliance with air emission standards (See Table 9).

Preliminary modeling of the air stripper performance using recent groundwater data from the site and the expected flow rate indicate that the treated groundwater will meet the surface water discharge standards without further polishing or treatment (See Table 9). The model also shows that air emissions will be significantly below the emission standard of 2.5 lbs/day.

Effluent samples will be collected from the groundwater treatment system at a rate required to satisfy regulatory requirements (which is assumed to be weekly for the first month and semiannually thereafter). All groundwater and effluent samples are assumed to be tested for all COCs. Sampling is assumed to continue for 5 years.

The groundwater pump-and-treat system will address contamination in the source area. The distal ends of the plume will be treated by natural attenuation. Groundwater monitoring will be performed to track the long-term progress and effectiveness of the groundwater remediation system. To perform the groundwater monitoring accurately, 1 additional well (POC2) will be installed. As was shown In Figure 4, the well will be located at the edge to Pipe Elm Branch. Samples will be collected and analyzed from five wells semiannually.

Alternative 5

Cost Category	Cost ($)
Capital	190,000
Annual Operations and Maintenance	28,000
Present Worth	260,000

This alternative is considered capable of complying with the chemical-specific (e.g., MCLs) and action-specific (e.g., active land treatment, waste handling, and long-term monitoring) ARARs (See Table 9). In addition to monitoring, institutional controls such as land-use and groundwater-use restrictions that prohibit use of the contaminated soil and aquifer will remain in place. This action will prevent human exposure to the groundwater, thereby averting a public health risk.

2.7 COMPARISON OF REMEDIAL ALTERNATIVES

This section provides a comparative analysis of the five remedial alternatives that were evaluated in detail in the FS and described in Section 2.6 of this ROD. The focus of the comparative analysis is on the relative advantages and disadvantages offered by each of the alternatives in relation to the seven evaluation criteria (excluding regulatory and community acceptance) that were analyzed. A detailed summary of this analysis is provided in Table 7, and an illustrative comparative summary is presented in Table 8.

2.7.1 Overall Protection of Human Health and the Environment

The overall protectiveness criterion is a composite of other evaluation criteria, especially short-term effectiveness, long-term effectiveness, and compliance with ARARs. All five of the alternatives are considered to be protective of human health because of institutional controls, such as land-use restrictions, that prohibit the unauthorized extraction or use of contaminated soil and groundwater on-base. The institutional controls, however, do not apply to off-base properties.

Alternative 1 (No Action) is not considered effective at protecting human health and the environment past the base boundary because no provisions are made to monitor the groundwater migration off-base or to evaluate compliance with the RAO.

Alternatives 2 (Natural Attenuation), 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Wall/Pump and Treat), and 5 (Pump and Treat) will all meet the RAOs and are considered highly protective of human health and the environment.

TABLE 7

Comparative Analysis of Alternatives for WP14/LF15

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Description	No Action	In situ remediation of WP14/LF15 groundwater using natural attenuation.	In situ remediation of WP14/LF/15 groundwater using density-driven convection.	In situ remediation of WP/14/LF/15 groundwater using permeable reactive barrier walls.	Ex situ treatment of WP/14/LF15 groundwater using air stripping.
Overall Protection					
ò Human Health Protection	Offers a high level of overall protection of human health through the existing land-use restrictions on-Base, but cannot be guaranteed effective past the Base boundary.	Offers a high level of overall protection of human health through the existing land-use restrictions on-Base. Biodegradation of source are constituents allow achievement of RAOs off-Base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-Base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-Base as demonstrated through groundwater monitoring.	Offers a high level of overall protection of human health through the existing land-use restrictions. Active treatment of source area constituents allow achievement of RAOs off-Base as demonstrated through groundwater monitoring.
ò Environmental Protection	Does not provide a mechanism to monitor ground-water constituent concentrations. Therefore, potential impacts to surface water from discharging groundwater cannot be assessed.	Groundwater constituents discharging to surface water meet MCLs off-Base.	Groundwater constituents discharging to surface water meet MCLs off-Base	Groundwater constituents discharging to surface water meet MCLs off-Base	Groundwater constituents discharging to surface water meet MCLs off-Base. Groundwater released to surface water through pump and treat operations will meet surface water quality criteria.
Compliance with ARARs					
ò Chemical-Specific ARARs	Success at meeting RAOs will be determined.	Natural attenuation is considered capable of maintaining RAO compliance.	Density-driven convection treatment is considered capable of maintaining RAO compliance.	This technology is capable of maintaining RAO compliance.	Pump and treat system considered capable of maintaining RAO compliance. Air stripper system will comply with DRGCAP requirements

TABLE 7 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
ò Action-Specific ARARs	Does not provide for long-term groundwater monitoring.	Long term groundwater monitoring is provided.	Complies with DRGHW for active land treatment. Long-term groundwater monitoring provided.	Complies with DRGHW for active land treatment. Long-term groundwater monitoring provided.	Long-term groundwater monitoring provided.
Long-term Effectiveness and Permanence					
ò Magnitude of risk	Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-Base. However, this alternative provides no mechanisms to determine whether the RAOs are achieved over time (i.e., preventing risks due to off-base migration of contaminants above RAO levels.)	Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-Base. Risk for potential off-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-Base. Risk for potential off-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-Base. Risk for potential off-Base users will be reduced as contaminant levels are lowered.	Because DAFB is expected to remain active for the foreseeable future, the land-use restrictions provided under this alternative are considered to provide long-term protection of human health on-Base. Risk for potential off-Base users will be reduced as contaminant levels are lowered.
ò Reliability of Controls	Land use restrictions enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Off-Base, the reliability of this alternative is questionable because there is no mechanisms to determine whether the RAOs are being met.	Land use restrictions enforced by DAFB are considered extremely reliable in preventing on-Base exposure. The 2-year study conducted by the USGS indicates that natural attenuation can be relied upon to achieve the RAOs beyond the Base boundary.	Land use restrictions enforced by DAFB are considered extremely reliable in preventing on-Base exposure. The DDC technology is considered reliable. However, because operation of the DDC system will change the redox condition of the aquifer in the source areas, high efficiency removal of the polychlorinated consitituents will be required.	Land use restrictions enforced by DAFB are considered extremely reliable in preventing on-Base exposure. Treatability studies are required to design the reactive barrier walls. Reductions achieved via abiotic reactions catalyzed by the reactive metal will supplement the active biodegradation processes.	Land use restrictions 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 The proposed technologies are proven and highly reliable

TABLE 7 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
ò Type and Quality of residue	No residues generated	No residues generated	Spent activated carbon will be generated from air treatment.	No residues generated	Metals pretreatment generated small volumes of sludge which will require disposal.
Short-term Effectiveness					
ò Protection of Community During Remedial Action	No short term impact on the community surrounding the site.	No short term impact on the community surrounding the site.	No significant risk to the community surrounding the site during construction or operation.	No significant risk to the community surrounding the site during construction or operation.	No significant risk to the community surrounding the site during construction or operation.
ò Protection of Workers During Remedial Action	Not applicable.	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.	Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction.	Worker's exposure will be minimized by applying dust control techniques and providing personal protection equipment during construction.
ò Environmental Impact	None	Minimal disturbance will result from installing three new monitoring wells. Environmental impacts related to construction are minimal.	Moderate land disturbance due to installment of a number of wells throughout the sites. Environmental impacts related to construction are minimal.	Moderate land disturbance due to installation of barrier walls and grout curtains. Environmental impacts related to construction are minimal.	Moderate land disturbance due to installation of barrier walls and grout curtains Environmental impacts related to construction are minimal. Discharge of treated groundwater to Pipe Elm Branch not expected to adversely impact the environment.
ò Time Required	Unknown. This alternative does not monitor for RAO compliance.	It is predicted that RAOs will continue to be met while contaminants naturally degrade. Data will be evaluated after 5 years of monitoring to determine whether contaminant concentrations are significant enough to warrant continued monitoring.	It is predicted RAO compliance will be maintained during the course of remediation. Two years of source area treatment is estimated.	It is predicted RAO compliance will be maintained during the course of remediation. Five years of treatment at WP14/LF15 is estimated.	It is predicted RAO compliance will be maintained during the course or remediation. Two years of source area treatment is estimated.

TABLE 7 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Reduction of Toxicity, Mobility, and Volume					
ò Treatment Process Used	Not applicable.	Dominant process is biodegradation. Other attenuation processes include volatilization adsorption, and dilution.	Source area treatment using density-driven convection combined with soil vapor extraction (SVE). Distal ends of plumes treated by natural attenuation processes.	Source areas treated in situ via reductive dehalogenation Distal ends of plumes treated by natural attenuation processes.	Source area groundwater addressed by extraction followed by metals pretreatment and air stripping. Sludge generated during metals pretreatment will be sent offsite for disposal Distal ends of plumes treated by natural attenuation processes
ò Amount Treated	Not applicable.	Area covered by WP14/LF15 is approximately 4 acres.	Area covered WP14/LF15 is approximately 4 acres.	Area covered by WP14/LF15 is approximately 4 acres.	Area covered WP14/LF15 is approximately 4 acres.
ò Reduction in toxicity, mobility, and volume through treatment	None demonstrated.	Reduction in groundwater toxicity achieved through natural attenuation processes. No reductions in mobility or volume.	DDC process reduces groundwater toxicity in the source area. Contaminant mobility is increased during treatment, but mobilized contaminant should be captured by SVE. Natural attenuation reduces the toxicity of the distal ends of the plumes.	In situ reductive dehalgenation reduces groundwater toxicity in source areas. The technology does not impact the volume of contamination. Natural attenuation reduces the toxicity of the distal ends of the plumes.	Groundwater extraction will provide hydraulic control of the source areas thereby reducing or the mobility of contaminants away from the EMU. Removal of volatile organic constituents present in groundwater by air stripping will reduce the toxicity of groundwater. The volume of contaminated media is not affected. Natural attenuation reduces the toxicity of distal ends of the plumes.
ò Irreversibility of Treatment	Not applicable.	Natural attenuation will provide permanent removal of constituents through irreversible processes.	DDC treatment results in permanent removal of constituents through irreversible processes.	Reductive dehalogenation treatment results in the permanent removal of constituents through irreversible processes.	Air stripping treatment results in the permanent removal of constituents through irreversible processes

TABLE 7 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Implementability					
ò Ability to Construct and Operate Technology	Not applicable	This alternative requires the installation of monitoring wells. No difficulties are anticipated.	No difficulties are anticipated in installation of the DDC/SVE wells or equipment. Operation of the DDC system is straight forward.	No difficulties are anticipated in construction of the barrier wall or grout curtains.	No difficulties are anticipated in construction of groundwater extraction wells and operation of selected technologies.
ò Reliability of Technology	Not applicable	USGS confirms ongoing natural attenuation in the EMU. Continued attenuation of constituents is anticipated in the future.	DDC and SVE are reliable technologies for removal and destruction of VOCs in homogenous permeable soils. However, presence of clay layers in the EMU reduces the reliability of these technologies.	Technology is innovative and has been minimally field tested. However, technology is extremely simple. Very little to go wrong.	Air stripping technology is high reliable for removal of volatile organic constituents
ò Ease of Undertaking Additional Action	Not applicable	Additional actions could easily be performed if necessary.	If contaminant rebound occur that may result in RAO failure, additional remediation can be performed by restarting the in situ treatment. The DDC/SVE well networks could be expanded or scrapped and replaced with new technologies if necessary.	Reactive barrier wall placement is permanent. However, additional actions could easily be performed if necessary.	If contaminant rebound occurs that may result in RAO failure, additional remediation can be performed by restarting the treatment system. The extraction network and/or treatment system could be expanded or augmented if necessary, or replaced with new technologies
ò Ability to Monitor	Not applicable	Performance of natural attenuation is easily monitored.	Performance of the DDC system is easily monitored.	Performance of the reactive barrier walls is easily monitored.	Performance of the reactive barrier walls and pump and treat systems are easily monitored.
ò Regulatory Agency Coordination/Approval	None.	Coordination with appropriate personnel at DAFB is necessary Groundwater wells will require State permits.	Coordination with appropriate personnel at DAFB is necessary Groundwater wells will require State permits.	Coordination with appropriate personnel at DAFB is necessary. Groundwater wells will require State permits.	Effluent limits set by DNREC's NPDES branch have to be met prior to discharge to surface water Groundwater wells will require State permits.
					Coordination with the appropriate personnel at DAFB is necessary

TABLE 7 (cont'd)

Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
ò Availability of Services	Not applicable.	Readily available.	The density-driven convection component will require a specialty contractor, however, the remaining portions of this alternative are readily available.	Reactive metal barrier will require a specialty contractor	Readily available
ò Availability of Equipment	Not applicable.	Readily available.	Readily available.	Readily available.	Readily available.
ò Availability of Technology	Not applicable.	In place.	Readily available.	Readily available.	Readily available.
Cost (IRP Site WP14/LF15)					
Capital Cost	$0	$4,200	$150,000	$1,200,000	$190,000
Annual O&M Cost (first year)	$0	8,400	20,000	18,000	28,000
Net Present Worth Cost	$0	40,000	210,000	1,300,000	260,000

2.7.2 Compliance with ARARs

The RAOs that have been established for the EMU sites are based on achievement of the base-specific background concentrations and MCLs across the area of attainment. Alternative 1 (No Action) provides no mechanism to evaluate compliance with the MCLs and therefore does not comply with ARARs. The treatment actions and groundwater monitoring provisions of Alternatives 21 through 5 will result in demonstrated compliance with the MCLs. A summary of the ARARs used in the evaluation of the alternatives is provided in Table 9. Table 9 specifies which ARARs are applicable to each alternative.

A number of other ARARs--including the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act--must be considered for Alternatives 3, 4, and 5. Primary among them are compliance with VOC emission limitations to the atmosphere, land treatment regulations, and effluent discharge limitations to surface water. All of the action alternatives will comply with all ARARs.

2.7.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers primarily the magnitude of residual risk that would remain after the implementation of an alternative and the adequacy and reliability of the controls instituted. All of the alternatives provide for the long-term protection of human health through the existing land-use restrictions. However, reliance upon land-use restrictions is considered neither a permanent remedy nor applied to off-base property.

Under Alternative 1 (No Action), the contamination in groundwater will not be monitored. Therefore, as groundwater migrates from the EMU off-base, the adequacy and reliability of this alternative cannot be established. Hence, the long-term protectiveness of this alternative cannot be demonstrated.

All of the action alternatives employ remedial measures to control the source areas and rely upon natural attenuation to address the distal ends of the plumes. The magnitude of residual contamination residing in the source area is dependent on the time allowed for the remediation to continue. For Alternative 2 (Natural Attenuation), physical, chemical, and biochemical attenuation processes will continue to reduce contaminant concentrations indefinitely into the future. Alternatives 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Walls/Pump and Treat), and 5 (Pump and Treat) will all be operated and/or maintained for finite periods of time until high levels of confidence are reached that natural attenuation can address remaining contamination.

All four action alternatives are considered reliable. The efficacy of Alternative 2 was proven in a 2-year natural attenuation study by the USGS at the EMU sites. The technologies associated with Alternative 3, 4, and 5 have been applied successfully at other installations.

2.7.4 Reduction of Toxicity, Mobility, and Volume

Reduction in toxicity, mobility, or volume will not be documented with the implementation of Alternative 1 (No Action). While dilution and dispersion of all contaminants occurs naturally, only the organic contaminants will degrade, and it cannot be demonstrated that the RAOs will be met at the base

Table 9. Summary of ARARs

Environmental Laws and Regulations	Consideration as an ARAR	Retain for ARAR Analysis?
1. RCRA (42 USC 6901-92k. esp. 6921-39e), Delaware Hazardous Waste Management Act (7 Del. Code Ann. 6301-19. esp. 6306-07), Delaware Solid Waste Management Act (7 DO Code Ann. 6401-60)		
A. Delaware Solid Waste Disposal Regulations (DNREC Regulations Governing Solid Waste)	A solid waste landfill will not be constructed on-base.	No
B. Delaware Hazardous Waste Management Regulations (DNREC Regulations Governing Hazardous Waste (DRGIIW)		
1. Closure and Postclosure (DRGHW Part 264, Subpart G)	Waste will not be contained in place.	No
2. Groundwater Monitoring and Protection (DRGIIW Part 264, Subpart F)	Groundwater monitoring shall be conducted in accordance with monitoring criteria.	Yes
3. Standards applicable to containers and tanks (DRGHW Pan 264, Subpart I and J)	Contaminated groundwater may be temporarily stored on-site in tanks or containers awaiting treatment	Yes
4. Standards applicable to surface impoundments, waste piles, land treatment facilities (other than closure and post-closure requirements) (DRGIIW Part 264, Subpart K, L, and M)	In Situ treatment technologies such as air sparging and soil vapor extraction may be considered land treatment. Excavated soil may be temporarily stored in piles awaiting shipment for off-site disposal.	Yes
5. Location Standards (DRGHW Pan 264.18)	The site is not located in a 100-year floodplain, as defined by RCRA.	No
6. Transportation Standards (DRGHW Pan 263)	Any shipment of hazardous waste off-base must comply with transporter standards and manifesting requirements.	Yes
7. Incinerator Standards (DRGHW Part 264, Subpart 0)	On-site incineration is not considered a remedial alternative	No
8. Landfill Standards (DRGHW Part 264, Subpart N),	A hazardous waste landfill will not be constructed on-base.	No
9. Underground Storage Tank Regulations (Delaware Regulations Governing USTS)	UST rules are not applicable to remedial alternatives for this site	No
10. Land Disposal Restrictions (DRGIIW Part 268)	Land disposal restriction and treatment requirements shall be met with respect to residuals generated by the alternatives under consideration	Yes

Table 9. (cont.) Summary of ARARs

Environmental Laws and Regulations		Consideration as an ARAR	Retain for ARAR Analysis?
II	Delaware Environmental Control Act (7 Del. Code Ann, 6001-93) and Delaware Water Pollution Control Regulations (II Code of Del. Reg. 70 500 005)		
	A. Delaware National Pollutant Discharge Elimination System (NPDES) Regulations (Delaware Water Pollution Control Regulations (DWPCR) Section 4	Discharges to surface water would ave to meet NPDES requirements.	Yes
	B. Delaware Industrial Waste Effluent Limitations (DWPCR Sections 8)	Effluents generated by site remedial activities may require pretreatment Any effluent discharge to POTWs must meet pretreatment standards	Yes
	C. Delaware Water Quality Standards (DNREC Surface Water Quality Standards)	Remedial alternatives resulting in discharge to surface water may affect water quality.	Yes
III.	Clean Water Act, 33 USC 1251-1387, esp. 1311-17		
	A. Effluent guidelines (40 CFR 403)	Effluents discharged to a POTW would be subject to general pretreatment guidelines	Yes
	B. Ambient Water Quality Criteria (AWQC) (Federal Register 1980, 1985)	Erosion of soil during remediation activities may affect the surrounding	Yes
IV.	Safe During Water Act (SDWA), 42 USC 300F		
	A. Underground Injection Control (40 CFR Parts 144-147)	Extracted groundwater may be reinjected under some remedial alternatives.	Yes
	B. Maximum Contaminant Levels (MCLs)(40 CFR Parts 141 and 143)	Some compounds exceed their MCLs in groundwater, remedial action shall reduce contaminants to below MCLs.	Yes
V.	Marine Protection, Research, and Sanctuaries Act.		
	A. Incineration at sea requirements (40 CFR Part 761)	No wastes for the site will be incinerated at sea	No
VI.	Toxic Substances Control Act (TSCA)		
	A. Polychlornated biphenyls (PCB) requirements (40 CFR Part 761)	PCBs are not present at the site	No

Table 9. (cont.) Summary of ARARs

Environmental Laws and Regulations		Consideration as an ARAR	Retain for ARAR Analysis?
VII.	U. S. Army Corps of Engineers Program		
	A. Dredge and fill (33 CFR Part 323)	Remedial alternatives under consideration will not involve dredging or filling in of a navigable waterway.	No
	B. Construction in waterways (40 CFR Pare 323)	No construction in navigable waters will be required for the remedial actions under consideration.	No
VIII.	Clean Air Act (CAA)(42 USC Sections 7401-7671q)		
	A. National Ambient Air Quality Standards (NAAQS) (40 CFR Part 50)	Groundwater treatment alternatives may involve emissions to air.	Yes
IX.	Delaware Regulations Governing the Control of A Pollution (8 Code of Del.Reg.	Groundwater treatment alternatives may involve emissions to air	Yes
X.	U S. Department Transportation Regulations (49 CFR Parts 170 -179)	Waste may be transported off-silt for treatment or disposal under the considered remedial alternatives.	Yes
X1.	Response in a Floodplain or Wetlands (40 CFR Part 6. Appendix A, and Executive Orders 11988 and 11990	The site is not located within a 100-year floodplain	No
XII.	Conservation of Wildlife Resources (Endangered Species Act, 16 USC 1531; 50 CFR 200, 50 CFR 402)	Threatened or endangered species are not found at the site, If they are found, remedial action shall be implemented so as to conserve threatened or endangered species or resources.	No
XIII.	Wild and Scenic Rivers Act (16 USC 1274; 50 CFR 27)	No wild and scenic rivers are found in the vicinity of the site.	No
XIV.	Preservation of Scientific, Historic, or Archaeological Data (National Historic Preservation Act,16 U.S.C. 470, 40 CFR 6.301(b), 36 CFR 800; Archaeological and Historic Preservation Act of 1974, 16 U.S.C. 469, 40 CFR 6.301 (c); Historic Sites, Buildings, and Antiquities Act, 15 U.S.C. 461-467,40 CFR 6.301(a), 36 CFR Part 65)	Scientific, historic, or archaeological sites arc located in the vicinity of the site. Consultations with State Historic preservation officials, have been made.	Yes
XV.	Delaware Erosion and Sedimentation Act (7 Delaware Code Annotated Chapter 40)	Alternatives resulting in the disturbance of soil will require measures to Control erosion.	Yes

boundary for all contaminants over time. The four action alternatives include components that are capable of reducing significantly the toxicity and/or mobility of contaminants in groundwater through irreversible treatment processes.

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Alternative 2 (Natural Attenuation) relies upon a variety of physical, chemical, and biochemical processes to achieve reductions in contaminant concentrations and lowered groundwater toxicity. Anaerobic biodegradation is the dominant process.

Alternative 3 (Density-Driven Convection) uses an in situ technology to strip volatile contaminants from the source area and oxygenate the groundwater. Oxygenating the groundwater will stimulate aerobic biodegradation processes, which will augment one another to reduce groundwater toxicity.

Alternative 4 (Permeable Reactive Barrier Wall/Pump and Treat) uses two separate technologies. Contact with the reactive barrier wall causes contaminated groundwater to undergo an abiotic reductive dehalogenation reaction, thus reducing the toxicity of the groundwater. The pump-and-treat component creates a hydraulic barrier to contaminant migration, thus limiting mobility. Treatment of the extracted groundwater using air stripping reduces its toxicity.

Alternative 5 (Pump and Treat) offers the benefits of extraction and treatment discussed for Alternative 4, but includes all of the EMU sites.

All of the action alternatives satisfy the CERCLA statutory preference for treatment.

2.7.5 Short-Term Effectiveness

Alternative 1 (No Action) provides no remedial actions. Therefore, no short-term effects on community or worker health or the environment will result from construction activities. However, because Alternative 1 does not provide monitoring to ensure compliance with the RAOs established for this project, it is considered to be ineffective.

Alternatives 2 (Natural Attenuation), 3 (Density-Driven Convection), 4 (Permeable Reactive Barrier Wall/Pump and Treat), and 5 (Pump and Treat) will be effective in reducing groundwater contaminant concentrations in the EMU. None of the alternatives is expected to have significant impacts on worker or public health or the environment.

Alternative 2 is currently meeting the RAOs and is projected to continue meeting them in the future. Alternative 3 will change the redox character of the source areas from anaerobic (reducing) to aerobic (oxidative). An aerobic environment is less conducive to the biodegradation of polychlorinated alkenes than an anaerobic environment, thus the DDC system operation will have to continue until the polychlorinated compounds are removed to low levels. DDC system operation is estimated to continue for 2 years. Alternative 4 includes the permanent installation of reactive barrier walls, which will greatly enhance the rate of abiotic reductive dehalgenation reactions. These abiotic reactions augment the naturally occurring biodegradation reactions. Maintenance of the barrier wall is estimated to continue for 5 years. The pump-and-treat components of Alternatives 4 and 5 are estimated to continue for 2 years.

2.7.6 Implementability

Three main factors are considered under this criterion: technical feasibility, administrative feasibility, and availability of services and materials. All five alternatives are administratively feasible, and the required services and materials are readily available. Hence, the comparison will focus on the technical feasibility of implementing the alternatives.

No technical feasibility considerations are associated with Alternative 1 (No Action). Of the action alternatives, Alternative 2 (Natural Attenuation) has by far the fewest implementability considerations. Because the USGS natural attenuation study in the EMU has already been completed, long-term groundwater monitoring is the only component remaining and is easily implemented.

Alternatives 3 (Density-Driven Convection) and 4 (Permeable Reactive Barrier Wall/Pump and

Treat) are relatively the most complex systems to design, construct, and operate. Both of these alternatives require treatability studies before their design and include the most extensive construction. Alternative 3 includes installing and balancing a total of 31 DDC wells and 50 SVE wells across three sites, whereas Alternative 4 includes installing 750 linear feet of grout curtains and 375 linear feet of reactive barrier wall, all to depths of 40 ft.

Alternative 5 (Pump and Treat) involves systems that are much easier to design, install, and operate relative to the systems included under Alternatives 3 and 4, but it is still more complex than Alternative 2.

All of the technologies considered in the action alternatives are considered reliable and are easily monitored. None of the technologies precludes the implementation of additional remedial measures at a later time, if they are deemed necessary.

2.7.7 Cost

No direct costs are associated with the implementation of Alternative 1 (No Action). The estimated costs of the four action alternatives, including capital costs, annual O&M costs, and present net worth, are summarized in Table 10. Alternative 2 (Natural Attenuation) offers a substantial cost advantage over the other action alternatives with a present worth cost of $40,000. Alternatives 3 (Density Convection) and 5 (Pump and treat) offer higher present worth costs of $210,000 and $260,000, respectively. The present worth cost of Alternative 4 (Permeable Reactive Barrier Wall/Pump and Treat) is substantially more costly at $1,300,000.

2.7.8 Regulatory Acceptance

The USEPA and the State of Delaware have reviewed the alternatives and are in agreement with the selected remedy for WP14/LF15.

2.7.9 Community Acceptance

No comments were received during the public comment period and no community opposition to the preferred remedy was noted.

TABLE 10
Action Alternative Cost Summary
for WP14/LF15 (Area 1)

Alternative	Capital Cost	Annual O&M*	Net Worth
2. Natural Attenuation	$4,200	$8,400	$40,000
3. Density Driven Convection	$150,000	$20,000	$210,000
4. Permeable Reactive Barrier Wall	$1,200,000	$18,000	$1,300,000
5. Groundwater Extraction with Air Stripping	$190,000	$28,000	$260,000

* First year O&M costs.

2.8 SELECTED REMEDIAL ALTERNATIVE

The selected remedy for cleanup of soil and groundwater at WP14/LF15 is Alternative 2, which includes the following major components:

- natural attenuation,
- continued enforcement of existing land use restrictions,
- restrictions of groundwater use, and
- groundwater monitoring.

The reasoning to support the selected remedy for cleanup of groundwater at LF13 is summarized as follows:

- Natural attenuation is capable of meeting the RAOs. The USGS conducted an extensive natural attenuation study of the site and concluded that none of the COCs were currently migrating past the base boundary above MCL concentrations in either groundwater or surface water. In addition, the COCs are not predicted to migrate off-base in the future.
- Alternative 2 is considered protective of human health and the environment. It complies with all ARARs that address off-site migration or movement of contamination and reduces the toxicity of contaminants in the soil and groundwater.
- The technology offers good long-term and short-term effectiveness.
- Alternative 2 offers a great implementability advantage over all other alterative. The only component of Alterative 2 still requiring implementation is the long-term groundwater monitoring. Simple monitoring, well construction, and operation considerations are required in addition to the groundwater monitoring requirements. The monitoring program will verify the status of the groundwater contamination and, therefore, protect future receptors before exposure. The monitoring program is currently being developed in consultation with the USEPA and DNREC. As Alterative 2 is implemented, the monitoring program will provide the data necessary to verify that natural attenuation of groundwater contaminants is working.
- Alternative 2 offers substantially lower capital, O&M, and present worth costs than any of the other action alternatives. This cost advantage is particularly important given that all of the alternatives offer similar performance. There are no treatment by-products (e.g., spent carbon and sludges) produced and no hazardous chemicals (e.g., oxidizing agents) need to be stored on-site with Alternative 2.
- Institutional controls are already in place to limit access to or use of the site resources, including soil and groundwater.

DAFB, USEPA, and DNREC have agreed that the installation of additional monitoring points (i.e,. monitoring wells, well points, etc.) is necessary to help demonstrate that the remedial action will accomplish its intended goal and that if the additional data collected during the remedial action suggests otherwise, that the remedial action will be readdressed in the basewide ROD.

2.81 PERFORMANCE STANDARD FOR THE SELECTED REMEDY

The COCs in groundwater at this site, which are listed in Section 14 of this ROD, shall not exceed their respective federal MCLs at or beyond the boundary of DAFB. COCs that do not have an MCL shall not exceed DAFB-specific background levels at or beyond the boundary of DAFB,

The concentrations of the COCs in groundwater at this site, also listed in Section 2.4 of this ROD, shall be reduced to below federal MCLs (or, if no MCL exists, the DAFB-specific background level) within the area of attainment within a reasonable time, not to exceed 30 years. The area of attainment is the area outside the boundary of any waste that remains in place at the site and up to the boundary of the contaminant plume. Existing institutional controls, which are more fully described in DAFB's Real Estate Property Management System, and site use restrictions continue to remain in effect.

2.9 STATUTORY DETERMINATION

Based on consideration of the requirements of CERCLA, the comparative analysis, and comments, DAFB, USEPA, and the State of Delaware believe Alternative 2 provides the best balance of the trade-offs among the alternatives with respect to the criteria used to evaluate remedies. The selected remedy is consistent with CERCLA and, to the extent practicable, the NCP. The selected remedy is protective of human health and the environment complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, is cost-effective, and uses permanent solutions and alternative treatment to the maximum extent practicable.

The reliability of natural attenuation mechanisms, such as bio-degradation, adsorption/ desorption, and dilution for the cleanup of petroleum- and chlorinated-based media has been demonstrated at various sites around the country to be cost effective and, if properly monitored, an environmentally sound solution to soil and groundwater contamination. It results in permanent reduction in concentrations of contaminants in the subsurface. Investigative data show natural attenuation is already at work within the site area. Therefore, Alternative 2 is the selected remedial action for groundwater at Site WP14/LF15. Because the hazard index and LECR calculated for the different soil scenarios in the BRA are within an acceptable risk range, no further action than that already taken is determined to be appropriate for site soils.

GLOSSARY

air sparging - A process whereby air is pumped into the subsurface, groundwater, or soils to enhance the volatilization or aerobic biodegradation of compounds.

air stripper - A device to remove (strip) volatile organics from contaminated water by bringing the water into contact with air, causing volatile compounds to change from liquid phase to the vapor phase.

aquifer - A geologic formation capable of yielding water to wells and springs.

Applicable or Relevant and Appropriate Requirements (ARARs) - Criteria set forth by federal, state, or local regulations that must be considered in the evaluation of remedial alternatives and govern the environmental actions at a particular site.

Ambient Water Quality Criteria (AWQC) - Regulatory standards for surface water quality.

Baseline Risk Assessment (BRA) - A statistical evaluation of the current and future risks to human health and the environment from the exposure to contaminants at a site if no remedial actions are taken.

Benzene, toluene, ethylbenzene, and xylene (BTEX) - Chemical compounds that are common constituents of fuels and petroleum products.

biodegradation - The breakdown of organic constituents by microorganisms into less complex compounds.

bioremediation - The cleanup of a contaminated medium through natural biological processes.

bioventing - A treatment process that introduces air into the subsurface soils to stimulate the growth of microorganisms that naturally attack certain compounds. This process speeds up the rate at which some chemicals biodegrade.

Capital Cost - Cost incurred for the construction and startup of a facility.

Carcinogen - A chemical capable or suspected of producing cancer as a result of exposure.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - A federal law passed in 1980 and revised in 1996 by the Superfund Amendments and Reauthorization Act (SARA). CERCLA provides federal authority and money for the USEPA to respond directly to the release or threatened release of hazardous substances into the environment at inactive sites.

Density-driven convection (DDC)- An in situ process for removal of VOCs from the groundwater using air to strip contaminants from the water.

The State of Delaware Department of Natural Resources and Environmental Control (DNREC) State regulatory agency in charge of overseeing environmental programs at DAFB.

Delaware Regulations Governing the Control of Air Pollution (DRGCAP) - Regulatory protocols and standards for control of particulates and emissions to the air within the state.

Delaware Regulations Governing Hazardous Waste (DRGHW) - Regulatory protocols and standards for control of handling, transport, storage, and disposal of hazardous wastes within the state.

Electromagnetic (EM) - A geophysical survey instrument used to locate changes in specific conductance in subsurface materials.

Feasibility Study - A study to develop and evaluate options for remedial actions.

Granular activated carbon (GAQ - Carbon material that is has ironically charged sites capable of filtering organic and inorganic compounds from a waste stream.

Groundwater - Subsurface water residing in a zone of saturation.

Ground penetrating radar (GPR) - A geophysical survey instrument used primarily to locate changes in lithological character of the subsurface soil.

Hazard Index (HI) - An indicator of the health risk associated with exposure to a noncarcinogenic chemical.

in situ - In the original location (in the ground for this report).

Installation Restoration Program (IRP) - The Department of Defense (DOD) program designed to identify, report, and correct environmental deficiencies at DOD installations. At DAFB, this program implements the requirements for cleanup under CERCLA.

leachate - The solubilization and transport of constituents in soil through the percolation of surface water to groundwater.

Lifetime Excess Cancer Risk (LECR) - Represents the risk of exposure to cancer-causing compound over a lifetime.

Maximum Contaminant Level (MCL) - Federal drinking water standards enacted by the Safe Drinking Water Act.

Natural attenuation - A remediation approach that depends upon natural processes such as dilution, dispersion, sorption, volatilization, chemical transformation, and biodegradation, that act to contain contaminants, reduce contaminant concentrations, and restore soil and groundwater quality.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP) - The federal regulation that provides a contingency plan for discharges or releases of hazardous substances, pollutants, contaminants, or oil into the environment that may present an immediate danger to public health or welfare.

Operation and Maintenance Costs (O&M) - Annual costs incurred for operation and maintenance of a facility.

plume - A recognizable distribution of constituents in groundwater.

Selected Alternative - The clean-up strategy that offers the best chance of success in protecting human health and the environment from contamination at a site. The selected alternative is selected from several clean-up strategies because it satisfies USEPA criteria for effectiveness, implementability, cost, and public and regulatory acceptance.

Remedial Action Objective (RAO) - Clean-up goal established for remediation.

Reactive iron filings - For the case proposed in Alternative 4, metal shavings are placed in the path of a contaminant plume to act as a catalyst in the abiotic degradation of halogenated organic compounds. The plume is allowed to pass through a permeable wall that contains the iron filings. This actual physicochemical degradation process is also called dehalogenation.

Resource Conservation and Recovery Act (RCRA) - Federal law enacted to address environmental issues created by current waste disposal, spills, and handling practices.

Remedial Investigation (RCRA) - An investigation that involves sampling the air, soil, and water to determine the nature and extent of contamination at an abandoned waste site and the human health and environmental risks that result from that contamination.

Record of Decision (ROD) - A legal document that explains the specific clean-up alternative to be implemented at a Superfund site.

Superfund Amendments and Reauthorization Act (SARA) - A congressional act that modified CERCLA. SARA was enacted in 1986 and again in 1990 to authorize additional funding for the Superfund program.

Soil vapor extraction (SVE) - A process by which air and volatilized compounds are extracted from the subsurface soils through screened wells using a vacuum.

Toxicity Characteristics Leaching Procedure (TCLP) - An analytical procedure that measures the level of organic leachate from a soil sample. This method is commonly used to determine whether soil to be disposed of is hazardous.

Total Petroleum Hydrocarbons (TPH) - This analytical parameter is a measure of the hydrocarbons, often within a particular petroleum weight range.

U.S. Environmental Protection Agency (USEPA) - The federal regulatory agency in charge of overseeing environmental programs at DAFB.

vadose zone - Soil zone above the water table.

RESPONSIVENESS SUMMARY

The following Responsiveness Summary is a compilation of the comments and responses on the Proposed Plan for Natural Attenuation of Groundwater, Fire Training Area 3 (FT03), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997), Proposed Plan for Natural Attenuation of Groundwater, Liquid Waste Disposal Area 14 (WP14) and Landfill 15 (LF15), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997), and Proposed Plan for Natural Attenuation of Groundwater. Landfill 13 (LF13), Dover Air Force Base, Dover, Delaware (HAZWRAP, June 1997).

Dover Air Force Base (DAFB) offered opportunities for public input and community participation during the Remedial Investigation (RI)/FEASIBILITY Study (FS)and Proposed Plans (PP) for all three site in the East Management Unit. The PPs was made available to the public in the Administrative Record. Documents composing the Information Repository for the Administrative Record for the site are available at the Dover Public Library, Dover, Delaware. The notice of availability for the PPs was published in the local newspaper and the Base newspaper. A public comment period was held from Monday, June 16, 1997 until Wednesday, July 15, 1997. The public comment period was not extended as there were no requests for an extension. No written comments were received from the public and no public meeting was requested. These community participation activities fulfill the requirements of Section 113(k)(2)(B)(i-v) and 117(a)(2) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

Comments submitted by the U.S. Environmental Protection Agency (USEPA) and the State of Delaware Department of Natural Resources and environmental Control (DNREC), requested editorial changes and clarification of some issues; however, the editing and clarification did not result in any significant change to the preferred alternative presented in the PPs.

TIME CALCULATIONS FOR NATURAL ATTENUATION

<IMG SRC 97176H>