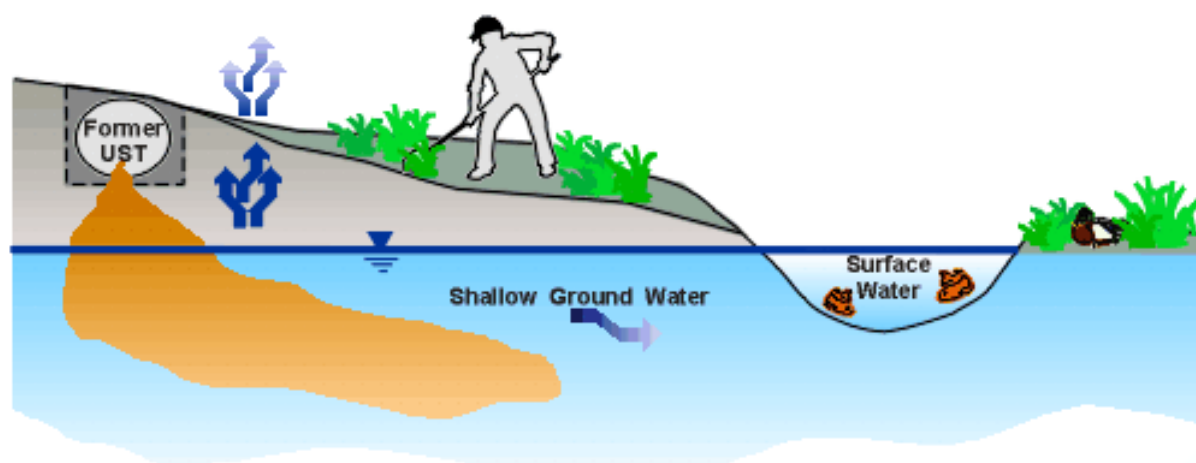


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Streamlined Risk-Based Closure of Petroleum Contaminated Sites Performance and Cost Results From Multiple Air Force Demonstration Sites

Technology Demonstration Summary Report



October 1999



**Air Force Center
for Environmental Excellence**

**STREAMLINED RISK-BASED CLOSURE OF PETROLEUM CONTAMINATED
SITES
PERFORMANCE AND COST RESULTS FROM MULTIPLE AIR FORCE
DEMONSTRATION SITES
TECHNOLOGY DEMONSTRATION SUMMARY REPORT**

October 1999

Prepared For

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ACRONYMS AND ABBREVIATIONS

AETC	Air Education and Training Command
AFB	Air Force base
AFCEE/ERT	Air Force Center for Environmental Excellence/Technology Transfer Division
ASTM	American Society for Testing and Materials
AVGAS	aviation gasoline
BTEX	benzene, toluene, ethylbenzene, and xylenes
bgs	below ground surface
BX	base exchange
CAP	corrective action plan
COC	chemical of concern
COPC	chemical of potential concern
DDC	density-driven convection
DEHNR	Department of Health and Natural Resources
FFS	focused feasibility study
IEUBK	Integrated Exposure Update Biokinetic (model)
LTM	long-term monitoring
MDEQ	Mississippi Department of Environmental Quality
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
MNA	monitored natural attenuation
NA	not analyzed
NFA	no further action
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbon
PEL	permissible exposure limit
RAP	remedial action plan
RBCA	risk-based corrective action
RBSL	risk-based screening level
SSTL	site-specific target level
SVE	soil vapor extraction
TCL	target cleanup
TLV	threshold limit values
TNRCC	Texas Natural Resource Conservation Commission
TPH	total petroleum hydrocarbons
USEPA	US Environmental Protection Agency
UST	underground storage tank

SECTION 1

PROJECT OVERVIEW

This document summarizes the results of streamlined risk-based corrective action (RBCA) assessments performed for nine US Air Force sites with fuel-contaminated groundwater. The project was performed for the Air Force Center for Environmental Excellence, Technology Transfer Division (AFCEE/ERT) under Air Education and Training Command (AETC) Contract No. F41689-96-D-0710, Order No. 5015. Details of the site-specific assessments are available in the individual corrective action plans.

1.1 SUMMARY OF THE RISK-BASED APPROACH

The objective of risk-based remediation is to reduce the risk of specific chemicals to human health and/or ecological receptors (i.e., nondomesticated plants and animals). For any chemical to pose a risk, four elements must exist at the site:

- A source of chemical contamination that exceeds or could generate chemical contamination above health-protective or aesthetic standards;
- A mechanism of contaminant release;
- A human or ecological receptor available for chemical contact; and
- A completed exposure route through which that receptor will contact the chemical.

If any one of these four elements is absent at a site, there is no current risk. The reduction or elimination of risk can be accomplished by limiting or removing any one of these four elements from the site.

The goal of this risk-based remediation approach was to find the most cost-effective method of reducing current and future potential risk by combining three risk-reduction techniques:

- Chemical source reduction - Achieved by natural attenuation processes over time or by engineered removals such as free product recovery, soil vapor extraction (SVE), or *in situ* bioventing.
- Chemical migration control - Examples include natural attenuation of a groundwater plume, and SVE to prevent migration of hazardous vapors to a receptor exposure point.
- Receptor restriction - Examples include land use controls and site fencing to control receptor exposure to site contaminants until natural attenuation and/or engineered remediation reduce the chemical source and/or eliminate the potential for chemical migration to an exposure point.

This project involved RBCA evaluations at nine sites in four states at which groundwater is contaminated with petroleum hydrocarbons. At all sites, benzene, toluene, ethylbenzene, and/or xylenes (BTEX) were primary chemicals of potential concern (COPCs).

1.2 PROJECT TASKS

The major tasks of this risk-based project were:

- Assessing available data and collecting any supplemental site characterization data necessary to define the nature, magnitude, and extent of soil and groundwater contamination and to document to what degree natural attenuation processes are affecting contaminant concentrations;
- Determining if an unacceptable risk to human health or the environment currently exists or may exist in the foreseeable future using future lands use plans, applicable regulatory guidance, contaminant fate and transport predictions, and exposure concentration estimates;
- Evaluating and recommending a remedial alternative that both reduces the source of contamination and minimizes or eliminates risks to potential receptors; and
- Documenting the remedial action selection process in a corrective action plan (CAP) that satisfies regulatory requirements.
- Whenever possible, obtaining site closure approval or approval of a site closure plan.

A primary objective of the project was to streamline and economize the implementation of the Air Force Natural Attenuation Protocol (AFCEE, 1995), thereby demonstrating the feasibility of using this approach at commercial/industrial (i.e., non-government) sites. The project was performed during the period from July 1997 to September 1999.

1.3 TEST SITE LOCATIONS AND SITE DESCRIPTIONS

The nine sites evaluated during this project are summarized in Table 1.1 and their locations are shown on Figure 1.1. All are sites at which petroleum hydrocarbon releases have resulted in groundwater contamination. Seven of the sites had a single, dissolved-contaminant plume emanating from a single source area. The remaining two sites (Randolph Air Force Base [AFB] and Tyndall AFB Base Exchange [BX] Service Station) each had two distinct source areas and contaminant plumes. In most cases, the specific contaminant release dates are not known. However, most of the releases occurred prior to 1992.

Engineered remedial actions, focusing primarily on source reduction, had been implemented at six of the nine sites prior to the performance of this project. Source reduction techniques included bioventing, SVE, soil excavation, and in-well density-driven-convection (DDC) aeration. In addition, a groundwater pump-and-treat system was operating to control plume migration at the Eglin AFB Seventh Street Service Station, and a single air sparging well was operating at the Eglin AFB Military Gas Station to reduce dissolved BTEX concentrations.

**TABLE 1.1
PROJECT SITES**

Site ID	Location	Contaminant Source	Release Date
Seventh Street Service Station	Eglin AFB, Florida	Leaking gasoline underground storage tanks (USTs) and associated piping	Prior to 1983
Military Gas Station	Eglin AFB, Florida	Leaking gasoline USTs and associated piping	Prior to 1991
BX Service Station, Area of Concern-A (ST-06)	Keesler AFB, Mississippi	Leaking gasoline USTs and associated piping	Prior to 1987
Building 4522	Seymour Johnson AFB, North Carolina	JP-8 aviation fuel leak in a valve pit	December 1995
Site ST-08 (Building 41105)	Pope AFB, North Carolina	Leaking #2 fuel oil USTs	Prior to 1992
Former Building 2093 Gas Station	Kelly AFB, Texas	Leaking gasoline USTs and associated piping	Prior to 1989
Base Exchange Service Station (Site ST019)	Randolph AFB, Texas	Leaking gasoline USTs and associated piping; release from an aviation gasoline (AVGAS) transmission pipeline	Prior to 1987 (fuel UST plume) 1996 (AVGAS pipeline plume)
Base Exchange Service Station	Tyndall AFB, Florida	Leaking gasoline USTs and associated piping	Prior to 1984 (former UST area) Prior to 1987 (current UST area)
Site FT-16	Tyndall AFB, Florida	Fire training activities	Prior to 1980

Figure 1.1. Air Force Streamlined Risk-Based Site Closure Initiative Locations



1.4 REGULATORY REQUIREMENTS

The nine project sites were located in four states: Florida, Mississippi, North Carolina, and Texas. Each of the four states in which the project sites are located have developed RBCA regulations or guidance for petroleum underground storage tank (UST) sites. The site-specific approaches were designed to comply with the state RBCA programs. The RBCA programs for each of the four states are briefly summarized in the following subsections.

1.4.1 Florida

Guidance for determination of remedial requirements for closure of petroleum-contaminated sites, including several mechanisms for determining matrix-specific cleanup criteria, has been developed by the Florida Department of Environmental Protection (FDEP, 1997). The regulations allow closure of petroleum release sites under several different scenarios, including:

- No-Further-Action (NFA) Proposal Without Conditions,
- NFA Proposal With Conditions, or
- Monitoring-Only Proposal for Natural Attenuation.

A remedial action plan (RAP) must be prepared for sites that do not meet the requirements for NFA or monitored natural attenuation (MNA). Closure of a site under the NFA-Without-Conditions alternative would allow unrestricted future use of the site (i.e., residential land use), and therefore the requirements and allowable contaminant levels under this alternative are the most restrictive. The NFA-With-Conditions alternative requires that appropriate institutional or engineering controls be implemented to limit receptor exposure. Sites seeking closure under this alternative are subject to potentially less stringent cleanup levels. MNA is a recognized means of remediating a site, with the goal of achieving the NFA cleanup target levels. However, natural attenuation is considered to be an appropriate remedy only if the site is anticipated to achieve the applicable NFA criteria in five years or less.

Matrix-specific Target Cleanup Levels (TCLs) for petroleum constituents are provided in "look-up" tables or through reference to other applicable regulations (i.e., state groundwater or surface water regulations). Contaminant concentrations in all affected media at a site must be below all applicable TCLs in order for the site to qualify for an NFA (with or without conditions) proposal. However, the rule also allows for the development of alternative cleanup standards based on a site-specific risk assessment for use in a With-Conditions-NFA-Proposal. These site-specific alternative cleanup standards can be used in place of those presented in the look-up tables.

1.4.2 North Carolina

Guidance for determination of soil and groundwater remedial requirements for closure of petroleum-contaminated UST-related sites is available from the North Carolina Department of Environment, Health and Natural Resources (DEHNR, 1998a, 1998b, and 1998c). Sites are classified as high, intermediate, or low risk based on the threat to

potential receptors, the potential future use of groundwater, explosion or fire hazard, contaminant concentrations in groundwater, and the presence or absence of free product. The level of reporting and remediation required is commensurate with the risk level. **State guidance requires that MNA be considered as a remedial option and used to the maximum extent possible.** Multiple sets of Tier 1 RBSLs are provided based on the risk level and land use. For low-risk sites, site closure with NFA can be approved. The guidance does not explicitly allow for the development of alternative, site-specific cleanup levels.

1.4.3 Mississippi

The UST Division of the Mississippi Department of Environmental Quality (MDEQ), Office of Pollution Control mandates cleanup levels for BTEX and total petroleum hydrocarbons (TPH). However, other cleanup levels may be considered using a tiered approach with risk-based analysis and screening of COPCs. Two options are allowed under state regulations:

- Tier 1: Using generic, risk-based screening levels (RBSLs) calculated by MDEQ (1996) and presented in “look-up” tables; or
- Tier 2: Based on the completion of a limited risk assessment, using site-specific human health risks to develop site-specific cleanup levels in accordance with American Society for Testing and Materials (ASTM, 1995) Standard 1739 (RBCA guidance for petroleum release sites).

A tiered approach would employ the Tier 1 screening criteria to determine if current site conditions warrant further evaluation of potential human health risks through a Tier 2 assessment. If the screening process (Tier 1) or limited risk assessment (Tier 2) indicates that no contamination is present above the selected site action levels, then no type of remediation is warranted, and the site can proceed to closure.

1.4.4 Texas

Published guidance (Texas Natural Resource Conservation Commission [TNRCC], 1994, 1997a, and 1997b) contains information regarding the RBCA process and the establishment of remediation targets for sites regulated by the Petroleum Storage Tank Division of the TNRCC.

The two options for risk-based analysis and screening of COPCs are:

- Plan A: Use specified methods, conservative assumptions regarding potential human exposure, and site-specific factors to calculate site cleanup levels (i.e., a “Tier 1” screening level); or
- Plan B: Complete a limited risk assessment using site-specific human health and/or ecological risks to develop site-specific cleanup levels (i.e., a “Tier 2” screening level).

A tiered approach would use the Plan A screening criteria to determine if current site conditions may warrant further action, and to evaluate potential human health risks that can be more accurately quantified in a Plan B assessment. If the screening process (Plan

A) or limited risk assessment (Plan B) indicates that no contamination is present above the appropriate site action levels, then no remediation is warranted and the site can proceed to closure.

Streamlined site closure criteria are presented for sites where future exposure potential is low. Depending on site conditions (e.g., stability of the plume, site restrictions), closure of low priority sites may be obtained by completing a closure request form and implementing appropriate institutional controls (e.g., water use within the impacted aquifer near the site).

SECTION 2

PROJECT TASKS

2.1 KICKOFF MEETING

A project kickoff meeting was held for each Base to familiarize Base and regulatory personnel with the project scope and objectives, and to permit information gathering and a site visit. Several project tasks were accomplished for each site, as described in the following subsections.

2.2 WORK PLAN

Draft and final work plans were prepared for each site. The work plan summarized:

- Applicable state guidance and regulations governing RBCA activities;
- Site background information;
- Proposed site characterization activities; and
- Proposed data analysis, fate and transport modeling, and report preparation.

2.3 FIELD SITE CHARACTERIZATION

An average of 4 to 5 days of field work was performed at each site to define the current nature, extent, and magnitude of regulated contaminants, assess changes in contaminant concentrations over time, and evaluate the occurrence of natural attenuation. A Geoprobe® was used at seven of the nine sites to collect subsurface soil samples and install small-diameter (i.e., 0.5-inch) groundwater monitoring points. At the remaining two sites (Kelly and Randolph AFBs, Texas), the depth to groundwater and the presence of subsurface gravel and cobbles prevented the use of a Geoprobe®. Therefore, soil borings at Kelly AFB were advanced and monitoring wells were installed by the US Army Corps of Engineers using a truck-mounted auger rig. At Randolph AFB, the required drilling and well installation was performed by another base contractor that was performing a concurrent investigation at that site. Groundwater sampling was performed using AFCEE (1995) approved procedures described in AFCEE (1995). Field meters and test kits were used to the extent possible to measure the concentrations of geochemical parameters for the natural attenuation evaluation.

On average, the following site characterization activities were conducted at the site:

- Five soil borings were advanced, eight subsurface soil samples were collected for laboratory analysis of contaminants, and three soil samples were collected for total organic carbon (TOC) analysis (Table 2.1);

**TABLE 2.1
ANALYTICAL PROGRAM**

Analyte ^{a/}	Soil	Groundwater	Soil Gas	Field or Fixed-Base Analysis
Aromatic VOCs	X	X	X	fixed-base
PAHs	optional	optional	NA ^{b/}	fixed-base
TPH	optional	optional	optional	fixed-base
Lead	optional	optional	NA	fixed-base
Dissolved Oxygen	NA	X	NA	field
Nitrate	NA	X	NA	fixed-base
Ferrous Iron	NA	X	NA	field
Sulfate	NA	X	NA	field
Sulfide	NA	optional	NA	field
Methane	NA	X	NA	fixed-base
Manganese	NA	optional	NA	field
Ammonia	NA	X	NA	field
Alkalinity	NA	X	NA	field
ORP	NA	X	NA	field
Temperature	NA	X	NA	field
Conductivity	NA	X	NA	field
pH	NA	X	NA	field
TOC	X	NA	NA	fixed-base

^{a/} VOCs = volatile organic compounds, PAHs = polynuclear aromatic hydrocarbons, TPH = total petroleum hydrocarbons, ORP = oxidation reduction potential, TOC = total organic carbons.

^{b/} NA = not analyzed.

- Two groundwater monitoring points were installed and an average of nine groundwater samples were collected for field and laboratory analysis from existing wells and the new monitoring points (Table 2.1);
- Two subsurface soil gas samples were collected for laboratory analysis from an average depth of 3 feet below ground surface (bgs);
- Two aquifer slug tests were performed; and
- The elevations of the two new monitoring points were surveyed.

The samples were analyzed either by AFCEE-approved fixed-base laboratories or in the field. Target analytes included known site fuel contaminants, analytes required under the applicable state regulations and/or guidance, and a suite of geochemical parameters for the natural attenuation assessment.

2.4 CORRECTIVE ACTION PLAN

Draft and final CAPs were prepared for each site. The CAPs described:

- Site characterization activities;
- Physical characteristics of the study area;
- Tier 1 analysis and identification of COPCs;
- The extent and magnitude of COPCs in the environment;
- Chemical fate assessment performed using evidence of contaminant attenuation over time, evidence of contaminant biodegradation via microbially mediated reduction/oxidation reactions, and the analytical model BIOSCREEN (Newell *et al.*, 1996);
- Tier 2 identification of final chemicals of concern (COCs);
- An optional focused feasibility study (FFS) consisting of development and evaluation of a maximum of three remedial alternatives in terms of effectiveness, implementability, and cost; and
- A long-term monitoring (LTM) plan for site groundwater.

An FFS was performed only if the chemical fate assessment indicated that natural attenuation alone would not achieve cleanup goals within 10 years.

2.5 FINAL MEETING

Final meetings were held for selected sites to brief regulators on the results and recommendations stemming from the RBCA study.

SECTION 3

PROJECT RESULTS

The results of the RBCA investigations at the nine Air Force sites are summarized in this section.

3.1 SITE CONTAMINATION SUMMARY

The areal extent of contamination (source area plus dissolved BTEX plume) at the sites ranged from 1.1 to 7 acres, and averaged 2.7 acres. The most common COPCs identified during Tier 1 screening included BTEX, naphthalene, and lead. Maximum BTEX and naphthalene concentrations in source area soils ranged from 0.01 milligrams per kilogram (mg/kg) to 2,193 mg/kg and 6.5 mg/kg to 46 mg/kg, respectively. Maximum dissolved BTEX, naphthalene, and lead concentrations in groundwater ranged from 133 micrograms per liter ($\mu\text{g/L}$) to 25,686 $\mu\text{g/L}$, 0.6 $\mu\text{g/L}$ to 510 $\mu\text{g/L}$, and 0.008 $\mu\text{g/L}$ to 62 $\mu\text{g/L}$, respectively.

3.2 TIER 1 SCREENING RESULTS

For each site, a Tier 1 screening was performed to compare maximum detected contaminant concentrations in sampled media to conservative, generic RBSLs that were typically available in State look-up tables. Three of the four states (Texas, Florida, and North Carolina) have developed RBSLs specifically for commercial/industrial sites for at least one medium. None of the four states had developed RBSLs for soil gas, and none provided guidance on evaluating the significance of contaminant concentrations in soil gas. Therefore, the degree to which soil gas concentrations posed an inhalation risk to onsite receptors was initially assessed by comparing them to Occupational Safety and Health Administration (OSHA) 8-hour time-weighted-average permissible exposure limits (PELs) (National Institute of Occupational Safety and Health [NIOSH], 1997) and time-weighted-average threshold limit values (TLVs) determined by the American Conference of Governmental Industrial Hygienists (1996).

COPCs that exceeded RBSLs in at least one sample are summarized by medium in Table 3.1. Benzene was the most common COPC (a groundwater COPC at five of the nine sites), and generally was the “risk-driver” due to its relative toxicity and mobility relative to the other organic COPCs. The polynuclear aromatic hydrocarbons (PAHs) benzo(b)fluoranthene and benzo(k)fluoranthene were COPCs only at Pope AFB Site ST-08, where the contaminant was #2 fuel oil.

TABLE 3.1
SUMMARY OF CHEMICALS OF POTENTIAL CONCERN

Analyte	Number of sites at which Analyte was Identified as a COPC ^{a/}		
	Soil	Groundwater	Soil Gas
Benzene	2	5	2
Ethylbenzene	1	4	0
Toluene	0	2	1
Xylenes	1	4	1
MTBE ^{b/}	0	1	-- ^{c/}
Naphthalene	0	3	--
Benzo(b)fluoranthene	0	1	--
Benzo(k)fluoranthene	0	1	--
Lead	0	4	--
TPH ^{d/}	0	3	--

a/ COPC = Chemical of potential concern.

b/ MTBE = Methyl tertiary butyl ether.

c/ "--" = Analyte not identified as a COPC.

d/ TPH = Total petroleum hydrocarbons.

3.3 NATURAL ATTENUATION ANALYSIS

At almost all of the sites, resampling of previously sampled locations indicated that organic contaminant concentrations in soil were decreasing over time. At five of the sites, the decrease could be attributed to the effects of weathering combined with engineered source reduction (bioventing, SVE, in-well DDC aeration, or product recovery) (see Appendix C). At the remaining two sites for which historical soil data were available, the decrease was attributed to natural weathering alone. At six of the nine sites (including three sites where engineered source reduction had been performed), historical groundwater quality data indicated that organic COPC concentrations were decreasing over time (Appendix C). Historical groundwater sampling data indicated that:

- Five of the 11 organic contaminant plumes sampled (two of the nine sites had two plumes each) appeared to be stable (neither expanding or receding to a significant degree);
- Two plumes appeared to be receding;
- The second-youngest plume (Seymour Johnson AFB) appeared to have expanded in the recent past; and
- Insufficient data were available to assess the stability of three of the plumes.

Groundwater assimilative capacities computed for each of the organic COPCs at the nine sites ranged from 3.0 milligrams per liter (mg/L) to 20.4 mg/L and averaged 10.7 mg/L. The assimilative capacity computed for the groundwater systems at eight of the nine sites exceeded the maximum total concentrations of COPCs, indicating that the aquifers theoretically have sufficient electron acceptor capacity to degrade the available organic COPC mass as a single pore volume of groundwater migrates through the contaminated area. At the remaining site (Eglin AFB Seventh Street Service Station), the computed BTEX assimilative capacity was approximately 13,000 µg/L, and the maximum detected dissolved BTEX concentration was 26,000 µg/L. Therefore, multiple pore volume flushes would be required to degrade the available COPC mass at this site. Biodegradation rates computed for the COPCs are summarized in Table 3.2. Based on the geometric mean decay rates, half-lives for COPCs ranged from 0.3 to 2.7 years.

TABLE 3.2
RANGE OF BIODEGRADATION RATES FOR COPCs

COPC ^{a/}	Number of Plumes for Which Rates Were Computed	Range (day ⁻¹)	Geometric Mean (day ⁻¹)	Half Life (Years)
Total BTEX ^{b/}	3	0.01-0.0026	0.005	0.4
Benzene	6	0.002-0.0067	0.004	0.5
Toluene	2	0.0027-0.017	0.007	0.3
Ethylbenzene	3	0.006-0.001	0.003	0.6
Xylene	2	0.0073-0.0033	0.005	0.4
Napthalene	1	0.0007	0.0007	2.7

a/ COPC = Chemical of potential concern.

b/ BTEX = Benzene, toluene, ethylbenzene, and xylenes.

3.4 CONTAMINANT FATE AND TRANSPORT

The fate and transport of dissolved organic COPCs in nine plumes at seven of the sites was assessed using the analytical model BIOSCREEN (Newell *et al.*, 1996). Typically, the migration and/or persistence of benzene was simulated because of its relative toxicity and mobility. At two sites, the migration of dissolved xylenes also was simulated due to high concentrations of this compound in the groundwater (Appendix C).

BIOSCREEN simulations for four of the nine plumes for which contaminant migration was simulated predicted that the dissolved COPC plume would expand in the downgradient direction in the future without additional engineered remedial action. Historical groundwater quality data for these four sites had indicated that one of the plumes was stable, one was expanding, and plume dynamics at the remaining two could not be ascertained based on the available data (Appendix C). Four of the remaining

plumes were simulated to be stable or receding, and the simulated plume dynamics at the ninth site could not be compared to a field-measured plume because the actual plume had not been fully delineated.

Based on the BIOSCREEN model results, the time for concentrations of COPCs to decrease below Tier 1 RBSLs without additional engineered remedial action varied from 1 year to more than 400 years, with a median value of 10 years (including results from both the first-order decay and instantaneous-reaction routines). Predicted compliance times using the instantaneous reaction routine were at least 40 percent faster than the first-order decay routine, most likely because the first-order decay routine assumes no biodegradation of dissolved constituents in the source zone.

For two sites, the BIOSCREEN model also was used to predict the plume behavior assuming that 80 percent of the contaminant source was removed over a period of 3 years via engineered remediation. The simulated effect of engineered source reduction was more rapid plume diminishment. The results of these simulations indicated that the time to achieve Tier 1 RBSLs would be reduced by 75 to 85 percent.

3.5 TIER 2 SCREENING

In cases where maximum concentrations of one or more target analytes exceeded Tier 1 RBSLs, the generic (default Tier 1) exposure scenarios were re-evaluated in a Tier 2 assessment. Tier 2 site-specific target levels (SSTLs) were calculated based on more realistic, site-specific exposure scenarios. Each of the nine streamlined RBCA sites was located on an active Air Force Base in a commercial/industrial area where institutional controls on land use could be enforced. Therefore, there were no current or expected completed exposure pathways to ecological receptors. None of the dissolved contaminant plumes were projected to impact groundwater or surface water supplies used for potable, irrigation, or industrial purposes, and surface soils generally were not impacted. The land use at each of the sites was projected to remain commercial/industrial. Therefore, realistic exposure scenarios generally included dermal exposure and inhalation risks posed to intrusive construction workers and aboveground site workers. In some cases, risks posed by incidental ingestion of contaminated soil or groundwater also were considered per state guidance.

The procedures and algorithms used to calculate Tier 2 SSTLs evolved over the course of the project. In the end, groundwater SSTLs were developed using guidelines set forth by ASTM (1995) and the US Environmental Protection Agency (USEPA, 1989, 1991, 1993, and 1997). The method used to calculate soil gas SSTLs was also based on the ASTM (1995) guidelines. The soil gas SSTLs for indoor inhalation exposure were calculated by estimating a site-specific attenuation factor that accounts for diffusion through the unsaturated zone and building foundation and dilution and mixing with air in an overlying building. After an acceptable risk-based indoor air concentration is established, the attenuation factor is applied to calculate an acceptable soil vapor concentration. The attenuation factor was derived using the Johnson and Ettinger (1991) model. SSTLs for soil were calculated using algorithms recommended by USEPA (1989 and 1992). In addition, recent updates from the USEPA Superfund Dermal Work Group were used to calculate soil SSTLs for the dermal contact exposure route.

Maximum detected contaminant concentrations exceeded Tier 2 SSTLs at only two sites (Appendix C). At one site, the groundwater benzene concentration exceeded the SSTL calculated to be protective of intrusive construction workers. At another site, the benzene concentration in soil gas exceeded the concentration calculated to be protective of future indoor receptors in the event that a regularly-inhabited building was constructed on top of the source area in the future. In summary, out of a total of 36 COPCs at the nine sites (Table 3.1), only two were deemed to be COCs based on realistic exposure assumptions.

The Tier 1 RBSLs and Tier 2 SSTLs for the BX Service Station at Tyndall AFB provide an example of how site-specific exposure assumptions can cause Tier 2 SSTLs to deviate from RBSLs (Table 3.3). The groundwater RBSLs are based on an assumption of unrestricted future use of the groundwater (i.e., use as a drinking water source). In contrast, the SSTLs computed for this site assume only minimal, incidental ingestion of groundwater at a rate of 0.04 liter per 8-hour day for a maximum of 46 days during the course of a construction project. These exposure parameters were developed by the Air Force for use at Eglin AFB, Florida, and have been reviewed and approved by FDEP.

The significance of the detected dissolved lead concentrations was evaluated using the USEPA (1994) Integrated Exposure Uptake Biokinetic (IEUBK) model, which provides an estimate of potential blood lead levels in children associated with exposure to all site media. This model indicated that the impacts of lead in soil and groundwater at the Tyndall AFB BX Service Station are not considered to be significant.

TABLE 3.3
GROUNDWATER SSTLS FOR TYNDALL AFB BX SERVICE STATION

Analyte	Matrix	Units ^{a/}	Maximum Detected Concentration	Tier 1 RBSL ^{b/}	Tier 2 RME SSTL ^{c/}
Benzene	Groundwater	µg/L	3,400	1	2,980
Toluene	Groundwater	µg/L	5,000	40	126,000
Ethylbenzene	Groundwater	µg/L	3,100	30	53,300
Xylenes	Groundwater	µg/L	16,000	20	1,160,000
TRPH ^{d/}	Groundwater	mg/L	41	5	-- ^{e/}
Lead	Groundwater	µg/L	62	15	--
Naphthalene	Groundwater	µg/L	320	20	26,000
MTBE ^{d/}	Groundwater	µg/L	1,300	35	41,800

^{a/} µg/L = micrograms per liter; mg/L = milligrams per liter.

^{b/} RBSL = generic residential risk-based screening level from FDEP (1997).

^{c/} RME SSTL = reasonable maximum exposure site-specific target level.

^{d/} TRPH = total recoverable petroleum hydrocarbons, MTBE = methyl tertiary butyl ether.

^{e/} "--" = SSTL could not be computed.

3.6 PROPOSED REMEDIAL ALTERNATIVES

MNA with institutional controls was evaluated as a potential remedial alternative at all sites. Engineered source reduction (in addition to engineered source reduction actions already being implemented) was evaluated for two sites because the fate and transport modeling predicted that Tier 1 RBSLs for groundwater COPCs would not be achieved within 10 years. In these two cases, the average cost for implementing source reduction combined with MNA and institutional controls was approximately \$500,000, compared to \$240,000 for MNA with institutional controls alone. The recommended remedial alternatives for the nine sites were as follows:

- Immediate site closure (Kelly AFB);
- Closure contingent on the results of future LTM (Eglin AFB Military Gas Station, Tyndall AFB Site FT-16, Keesler AFB, and Randolph AFB);
- Continued free product recovery until recoverable product is extracted, followed by site closure (Seymour Johnson AFB);
- MNA until SSTLs are achieved, followed by an inactive (but managed) status characterized by 5 years of monitoring (Tyndall AFB BX Service Station); and
- MNA combined with source area biosparging and SVE (Eglin AFB Seventh Street Service Station).

Remedial recommendations were not required for the Pope AFB site because our scope was limited to a risk-based characterization of the site.

3.7 LONG-TERM MONITORING

Of the sites where MNA was recommended, LTM consisted of monitoring an average of seven wells for an average of 9 years. Constituents recommended for analysis included the site COPCs, and geochemical natural attenuation indicator parameters. The recommended frequency of LTM ranged from quarterly to biennially (every other year) (Appendix C).

3.8 CURRENT STATUS OF SITES

The Kelly AFB site was granted immediate closure. Justification for site closure included the following:

- The plume is stable and has not migrated off-site;
- The current and expected future use of the site is as an industrial facility;
- The lack of beneficial use of the affected groundwater, which resides in a low-permeability aquitard;

- Remaining contaminant concentrations are protective for construction worker exposure; and
- Future monitoring of the site would occur as part of the Base-wide monitoring program.

The Randolph and Keesler AFB sites were granted closure contingent on the results of 2 to 5 years of LTM. The remaining six sites are still in regulatory or Air Force review, and final decisions regarding site closure have not been made.

SECTION 4

COST ANALYSIS

The average cost for implementing the streamlined RBCA process at the four sites is outlined in Table 4.1.

TABLE 4.1
AVERAGE STREAMLINED RBCA SITE COSTS

Labor	Actual Average Cost	Average Cost Assuming Geoprobe® Rental and Subcontracted Drilling
Kickoff Meeting/Site Visit	\$2,300	\$2,300
Work Plan ^{a/}	\$6,400	\$6,400
Field Site Characterization	\$6,100	\$6,200
Data Analysis and Reporting ^{b/}	\$14,800	\$14,800
Final Regulatory Meeting	\$2,300	\$2,300
Other Direct Costs		
Subcontractors ^{c/}	\$4,100	\$4,700
Travel ^{d/}	\$1,500	\$1,500
Field Equipment and Supplies	\$800	\$3,200
Other ^{e/}	\$1,200	\$1,200
Project Management ^{f/}	\$4,000	\$4,000
Average Cost per Site	\$43,500	\$46,600

^{a/} Includes draft and final versions, and gathering/analyzing available site data.

^{b/} Includes fate and transport modeling, calculating SSTLs, and draft and final report.

^{c/} Includes analytical laboratory and surveyor.

^{d/} Includes travel for meetings and field work.

^{e/} Includes shipping, reproduction, phone/facsimile, and computer usage.

^{f/} Includes monthly reporting, project controls, and subcontract management.

It should be noted that an AFCEE-owned Geoprobe® was used at most of the sites. The actual average costs in Table 4.1 reflect the use and upkeep of the Geoprobe®; however, there were no rental costs associated with its use. In addition, costs incurred for use of the US Army Corps of Engineers drilling rig at Kelly AFB are not reflected in the actual costs. Therefore, the estimated average costs per site, assuming rental of a Geoprobe® (\$3,000 per week for one week) and use of a drilling subcontractor for Kelly AFB (\$5,500), are also shown in the table. Project management costs include the preparation of detailed monthly reports for 27 months; the cost of this task could be reduced for sites where this level of reporting is not required.

SECTION 5

LESSONS LEARNED AND RECOMMENDATIONS

5.1 SITE CHARACTERIZATION

The site characterization should focus on meeting state-specific regulatory requirements and on obtaining sufficient data to defensibly support risk-based corrective action recommendations. Key characterization needs include resampling previously-sampled locations to assess the temporal variation in contaminant concentrations, identifying maximum contaminant concentrations, determining the downgradient extent of dissolved contaminant migration, determining the locations of potential receptor exposure points (e.g., water supply wells, surface water bodies, wetlands), and determining background and plume core concentrations of geochemical natural attenuation indicator parameters.

Site characterization costs can be reduced through the use of direct-push techniques to advance soil borings, collect subsurface soil samples, and install small-diameter monitoring points, and the use of field geochemical test kits in place of more expensive fixed-base laboratory analyses.

5.2 FATE AND TRANSPORT MODELING

Use of relatively simple, user-friendly analytical fate and transport models such as BIOSCREEN often is sufficient to estimate the persistence and migration of the dissolved plume. The ability of these types of models to simulate spatial heterogeneities in the aquifer or the contaminant source the effects of weathering and engineered source reduction is limited. However, the nearly ubiquitous occurrence of fuel hydrocarbon biodegradation is increasingly recognized by the regulatory community; therefore, use of simple screening models often is acceptable despite their limitations.

5.3 RISK ASSESSMENT

Performance of a streamlined risk assessment is benefited by early identification of and agreement on potential receptors, exposure pathways, and exposure parameters.

The analytical model(s) should adequately address the exposure scenario(s) of interest. For example, a widely accepted model for estimating volatilization from soil or groundwater into an excavated trench does not exist. Therefore, simplifying/conservative assumptions need to be made to assess potential risk to an intrusive worker via the inhalation exposure route. Both the USEPA (1996) *Soil Screening Guidance* and the ASTM (1995) RBCA standard present equations that can be used to address soil-to-groundwater leachability, volatilization of chemicals from surface soil to outdoor air, and

volatilization of chemicals from subsurface soils to indoor air. For a particular exposure scenario (e.g., inhalation of chemicals volatilized from groundwater into indoor air), fate/transport algorithms may only be available from a particular source (e.g., ASTM RBCA guidance).

The regulatory acceptance of analytical exposure models should be determined prior to use of such models. For example, does the regulatory agency accept the ASTM (1995) RBCA approach for assessing potential risks/hazards at petroleum-contaminated sites? Does the regulatory agency require the use of alternate algorithms for estimating exposure via a specific exposure route? Does the regulatory agency have specific RBCA guidance/algorithms? For example, the State of Florida requires the use of their algorithm derived to assess the potential risk/hazard from breathing chemicals volatilized from groundwater within an excavated trench.

Analytical models used to assess risk should be up-to-date and scientifically defensible. Recently a USEPA Superfund national dermal workgroup has updated the recommended approaches for assessing risks/hazards from dermal exposure to chemicals in soil and groundwater. Recent developments in exposure modeling can be viewed on the web page of the USEPA National Center of Environmental Assessment and the USEPA Superfund web page.

For the soil/groundwater-to-indoor/outdoor air volatilization pathway, it is possible to reduce the uncertainty by collecting and quantitatively analyzing soil gas samples. The ASTM (1995) RBCA models and/or the USEPA (1999) Superfund models can be modified to use soil gas vapor results directly, thereby significantly reducing the uncertainty associated with modeling volatilization of chemicals from soil into the soil pore space (i.e., the initial step of the model is eliminated).

5.4 VALUE OF SOURCE REDUCTION

- Without source reduction, groundwater contaminants at most sites would have exceeded Tier 1 cleanup goals for over 20 years.
- Regulatory agencies are more likely to accept monitored natural attenuation as a groundwater remedy at sites where active source reduction has occurred.
- Source reduction also reduces the risks to future intrusive workers and allows the site to be used with less institutional control.

5.5 GENERAL IMPLEMENTATION

- The closure process for petroleum contaminated sites is being streamlined by many states.
- The ability to limit receptor exposure to contamination via enforceable institutional controls is an important element in obtaining site closure agreements.
- It is feasible to perform the entire RBCA process, including a MNA assessment, for less than \$50,000 per site.

- Whenever possible, the RBCA process should be used to facilitate site closure at low-risk, petroleum-contaminated sites where future land use is primarily industrial commercial.

SECTION 6

REFERENCES

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APPENDIX A

CASE STUDY 1 – KEESLER AFB

BASE EXCHANGE SERVICE STATION, AOC-1 (ST-06)

Keesler Air Force Base Base Exchange Service Station, AOC-A (ST-06)

Site Name

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Base Exchange Service Station, Area of Concern – A (ST-06)

Location: Keesler Air Force Base, Mississippi

CERCLIS ID No.: NA

Regulatory Context: Lead agency is USEPA Region IV; however, UST-related guidelines and requirements of the Mississippi Dept. of Environmental Quality are being used. IRP site characterization report completed in 1991, and RCRA Facility Investigation Report completed in 1992.

TECHNOLOGY APPLICATION

Period of Performance: September 1997 – April 1999

Area of Contaminated Zone (source area plus dissolved plume): 4.0 acres

BACKGROUND

Waste Management Practice That Contributed to Contamination: leaking underground storage tank(s)

Site History: 10 MOGAS USTs removed in 1987; evidence of contamination showed that one or more of the tanks had leaked.

Remedy Selection: Bioventing system installed in 1993 and operated for 3 years. Density-driven convection (DDC) in-well aeration system installed in 1996 and operated at least through February 1998. Based on this RBCA analysis, recommended final remedial action is monitored natural attenuation because the site contamination does not currently (and will not in the future) pose a significant risk to potential receptors, the dissolved plume is stable and degrading, and institutional controls can be maintained with a high level of confidence.

SITE LOGISTICS/CONTACTS

(Provide name, address, telephone, e-mail)

Site Lead: Ms. Lisa Noble, 81st CES/CEVR, 508 L Street, Keesler AFB, MS 39534-2115, (601)377-5803, noblel@ces.kee.aetc.af.mil.

Oversight: Mr. Jim Gonzales, AFCEE/ERT, 3207 North Rd., Building 532, Brooks AFB, TX 78235-5363, (210) 536-4324, james.gonzales@hqafcee.brooks.af.mil.

Regulatory Contact: Mr. Robert Pope, USEPA Region IV, 61 Forsyth St., SW, Atlanta, GA 30303-3104, (404) 562-8506.

Mr. Bob Merrill, Mississippi DEQ, P.O. Box 10385, Jackson, MS 39289-0385, (601) 961-5171.

Prime Contractor: Mr. John Hicks, Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, (303) 831-8100, john.hicks@parsons.com

Additional Contacts: NA

MATRIX DESCRIPTION

MATRIX IDENTIFICATION

Type of Matrix Processed Through Technology System: RBCA study addressed soil, groundwater, and soil gas

CONTAMINANT CHARACTERIZATION

Primary Contaminant Groups and Concentrations Measured During Site Investigation:

Gasoline constituents, see attached Table 1 for concentrations of target analytes in soil and attached Figure 1 for distribution of total lead and BTEX in groundwater.

Contaminant Properties:

Based on Tier 1 screening, only lead in groundwater was identified as a contaminant of potential concern at the BX Service Station. Lead is a non-soluble, non-volatile element that is extremely persistent in both soil and water. Environmental processes may transform one lead compound to another; however, lead itself is not degraded.

MATRIX CHARACTERISTICS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant parameters for the application)

Parameter	Value	Measurement Procedure
Soil Classification	NA	NA
Clay Content and/or Particle Size Distribution	NA	NA
Additional Soil Characteristics (specify)	NA	NA

SITE GEOLOGY/STRATIGRAPHY/HYDROGEOLOGY

Describe heterogeneity, depth to groundwater, size and characteristics of applicable aquifers and units (especially important for in situ technologies)

Fine- to medium-grained sand to 20 feet below ground surface (bgs), underlain by a clay layer of unknown thickness. Groundwater present at 5 to 9 feet bgs. Average hydraulic conductivity of sand zone is 40 ft/day, calculated horizontal groundwater flow velocity is 0.8 ft/day.

TECHNOLOGY SYSTEM DESCRIPTION

PRIMARY TECHNOLOGY

Monitored natural attenuation

SUPPLEMENTAL TECHNOLOGY TYPES

Bioventing and density-driven convection in-well aeration

TABLE 1
SUMMARY OF SOIL ANALYTICAL DATA
BX Service Station, Area of Concern A (ST-06)
Keesler AFB
Biloxi, Mississippi

		Sample Locations, Intervals, and Dates											
		SBA-14 (7 - 8) ^{a/} 17-Feb-98	SBA-14 (9 - 11) 18-Feb-98	SBA-15 (9 - 10) 18-Feb-98	SBA-16 (11 - 12) 18-Feb-98	SBA-16 (9 - 10) 18-Feb-98	WEI-B3 SBA-17 (9.5 - 10.5) 18-Feb-98	SBA-18 (8.5 - 9.5) 18-Feb-98	WEI-B1 SBA-19 (6.5 - 8) 18-Feb-98	SBA-19 (8.5 - 10) 18-Feb-98	SBA-100 (8.5 - 10) 18-Feb-98	SBA-20 (6 - 7) 18-Feb-98	SBA-20 (9.5 - 10.5) 18-Feb-98
Analyte	Units												
Benzene	mg/Kg ^{b/}	0.0054U	0.017	NM	NM	NM	0.22	5.4U	0.0055U	0.28U	0.37U ^{c/}	4.6U	2.4U
Ethylbenzene	mg/Kg	0.0022U	0.0089	NM	NM	NM	0.09	4.2	0.0022U	0.28U	0.15U	1.9	0.95U
Toluene	mg/Kg	0.0054U	0.072	NM	NM	NM	0.75	12	0.0055U	0.11U	0.37U	4.6U	2.4U
Xylenes (total)	mg/Kg	0.0054U	0.034	NM	NM	NM	0.58	150	0.0055U	0.28U	0.37U	3.1J1 ^{d/}	10
Total BTEX	mg/Kg	0.0184U	0.1319	NM	NM	NM	1.64	166.2	0.0187U	0.95U	1.26U	5	10
Naphthalene	mg/Kg	NM	0.26U	NM	NM	NM	0.27	2.1	0.22U	0.12J1	0.22U	NM	10
Lead	mg/Kg	NM	0.46J ^{e/}	0.40J	NM	0.18J	0.34J	8.7	4.2	NM	2.2	1.1	7.4
Total Organic Carbon	mg/Kg	NM	NM	2000U	2970	2000U	NM	NM	NM	NM	NM	NM	NM

Notes:

a/ depth in feet below ground surface.

b/ mg/kg = Milligrams per kilogram.

c/ U = The analyte was analyzed for and is not present above the reporting limit.

d/ J1 = The analyte was positively identified and has a concentration between the method detection limit and the reporting limit.

e/ J = The analyte was positively identified, but the associated numerical value may not be consistent with the amount actually present in the environment.

The data should be considered as a basis of decision-making and are usable.

Analysis methods are SW7421 for lead, SW8020 for aromatic VOCs, and SW9060 for total organic carbon.

SBA-100 (8.5-10) is a duplicate of SBA-19 (8.5-10)

All analyses performed by Quanterra Laboratories of Arvada, Colorado

NM = Not Measured

BTEX = Benzene, Toluene, Ethylbenzene, and Total Xylenes

REMEDIAL SYSTEM DESCRIPTION AND OPERATION

A total of 9 monitoring wells will be sampled quarterly for 1 year, and then annually for 4 years to document the effects of natural attenuation and ensure that downgradient receptors are protected. Samples will be analyzed for aromatic volatile organics and geochemical natural attenuation indicator parameters. If the 5-year monitoring period confirms that contamination has remained below target cleanup levels, performance monitoring will cease and the site will be placed in an inactive (but managed) status.

OPERATING PARAMETERS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant operating parameters for the application.)

Parameter	Value
Example: Temperature	NA
Others (as appropriate)	NA

TIMELINE

(Provide dates for key activities for the application, focusing on events related to technology.)

Start Date	End Date	Activity
August 1997	August 1997	Kickoff Meeting
Sept. 1997	Nov. 1997	Project Work Plan (draft and final)
Feb. 1998	Feb. 1998	Field Site Characterization
March 1998	April 1999	Data Analysis and Corrective Action Plan (draft and final)
1999	2004	Long-term Monitoring

TECHNOLOGY SYSTEM PERFORMANCE**CLEANUP GOALS/STANDARDS**

Typical cleanup levels for soil and water at gasoline UST sites in Mississippi are 100 ppm BTEX and 18 ppm BTEX, respectively. In addition, the Mississippi Department of Environmental Quality (MDEQ) has developed generic, risk-based screening levels (RBSLs) that are available on “look-up” tables. The RBSLs vary according to the distance of the nearest receptor from the source area. The closest receptor to the site is the Back Bay of Bixoxi, located approximately 2,100 feet northeast of the site. The MDEQ look-up tables have RBSLs for receptors located 1,400 feet and 2,600 feet from the source. To be conservative, the 1,400-foot RBSLs were selected as the appropriate set of Tier 1 screening values. However, these values do not include a RBSL for lead. The USEPA (1994a) Office of Solid Waste directive on risk assessment and cleanup of residential soil lead recommends that soil lead levels less than 400 ppm be considered safe for residential use; this level was used as the RBSL for lead in soil. Table 2 compares the maximum site concentrations for each compound measured in soil to the appropriate RBSL.

As with soil, the 1,400-foot receptor RBSLs were selected as the appropriate set of Tier 1 screening values for groundwater. In addition, the USEPA MCL for lead of 15 µg/L was used as the RBSL for this constituent. Table 3 compares the maximum site concentrations for each compound measured in groundwater to the appropriate RBSL.

Maximum-detected concentrations of BTEX in soil gas were compared to the chemical-specific OSHA 8-hour time-weighted average PELs (Table 4).

Based on the above-described comparisons, only lead in groundwater was identified as a chemical of potential concern for the BX Service Station. The USEPA (1994b) Integrated Exposure Uptake Biokinetic (IEUBEK) model, which provides an estimate of potential blood lead levels in residential children associated with exposure to all site media (soil and

TABLE 2
COMPARISON OF MAXIMUM SITE SOIL CONCENTRATIONS
TO TARGET CLEANUP LEVELS
BX Service Station, Area of Concern A (ST-06)
Keesler AFB
Biloxi, Mississippi

Chemical Name	Units	Maximum Concentration Detected	Location of Maximum Detection	Date of Maximum Detection	Target Levels ^{a/}	Number of Times Exceeded
Total BTEX	mg/kg ^{b/}	166.2	SBA-18	18-Feb-98	100	1
Lead	mg/kg	8.7	SBA-18	18-Feb-98	400	0
Acenaphthene	mg/kg	NA ^{c/}	NA	NA	> res ^{d/}	0
Acenaphthylene	mg/kg	NA	NA	NA	> res	0
Anthracene	mg/kg	NA	NA	NA	> res	0
Benzene	mg/kg	0.22	SBA-17	18-Feb-98	> res	0
Benzo(b)fluoranthene	mg/kg	NA	NA	NA	> res	0
Benzo (g,h,i)perylene	mg/kg	NA	NA	NA	> res	0
Benzo(k)fluoranthene	mg/kg	NA	NA	NA	> res	0
Benzo(a)pyrene	mg/kg	NA	NA	NA	> res	0
Chrysene	mg/kg	NA	NA	NA	> res	0
Dibenzo(a,h)anthracene	mg/kg	NA	NA	NA	> res	0
Ethylbenzene	mg/kg	4.2	SBA-18	18-Feb-98	> res	0
Fluoranthene	mg/kg	NA	NA	NA	> res	0
Fluorene	mg/kg	NA	NA	NA	> res	0
Indeno(1,2,3-cd)pyrene	mg/kg	NA	NA	NA	> res	0
Naphthalene	mg/kg	10	SBA-20	18-Feb-98	> res	0
Phenanthrene	mg/kg	NA	NA	NA	> res	0
Pyrene	mg/kg	NA	NA	NA	> res	0
Toluene	mg/kg	12	SBA-18	18-Feb-98	> res	0
Xylenes, Total	mg/kg	150	SBA-18	18-Feb-98	> res	0

Notes: Shading indicates maximum site concentration is above target level.

^{a/} Total BTEX based on MDEQ Typical Cleanup Level (Table 1.1), lead based on USEPA (1994c), all other Target Levels based on MDEQ RBSL "look-up" tables and a distance to receptor of 1,400 feet.

^{b/} mg/kg = Milligrams per kilogram.

^{c/} NA = Not available.

^{d/} > res = the RBSL exceeds the expected soil residual contamination under free product (worst case) conditions.

TABLE 3
COMPARISON OF MAXIMUM SITE GROUNDWATER CONCENTRATIONS
TO TARGET CLEANUP LEVELS
BX Service Station, Area of Concern A (ST-06)
Keesler AFB
Biloxi, Mississippi

Chemical Name	Units	Maximum Concentration Detected	Location of Maximum Detection	Date of Maximum Detection	Target Levels ^{a/}	Number of Times Exceeded
Total BTEX	µg/L ^{b/}	22,400	MW8-3	20-Feb-98	18,000	1
Total Lead	µg/L	21	MW8-3	20-Feb-98	15	3
Acenaphthene	µg/L	1	MWA-11	20-Nov-92	>sol ^{e/}	0
Acenaphthylene	µg/L	10 U ^{c/}	NA ^{d/}	20-Nov-92	>sol	0
Anthracene	µg/L	10 U	NA	20-Nov-92	>sol	0
Benzene	µg/L	2,500	MW8-3	20-Feb-98	56,000	0
Benzo(b)fluoranthene	µg/L	10 U	NA	20-Nov-92	>sol	0
Benzo (g,h,i)perylene	µg/L	10 U	NA	20-Nov-92	>sol	0
Benzo(k)fluoranthene	µg/L	10 U	NA	20-Nov-92	>sol	0
Benzo(a)pyrene	µg/L	10 U	NA	20-Nov-92	>sol	0
Chrysene	µg/L	10 U	NA	20-Nov-92	>sol	0
Dibenzo(a,h)anthracene	µg/L	10 U	NA	20-Nov-92	>sol	0
Ethylbenzene	µg/L	1,700	MW8-3	20-Feb-98	>sol	0
Fluoranthene	µg/L	10 U	NA	20-Nov-92	>sol	0
Fluorene	µg/L	10 U	NA	20-Nov-92	>sol	0
Indeno(1,2,3-cd)pyrene	µg/L	10 U	NA	20-Nov-92	150.00	0
Naphthalene	µg/L	320	MW8-3	19-Nov-92	>sol	0
Phenanthrene	µg/L	10 U	NA	20-Nov-92	>sol	0
Pyrene	µg/L	10 U	NA	20-Nov-92	>sol	0
Toluene	µg/L	10,000	MW8-3	20-Feb-98	>sol	0
Xylenes, Total	µg/L	8,200	MW8-3	20-Feb-98	>sol	0

Notes: Shading indicates maximum site concentration is above target level.

^{a/} Total BTEX based on MDEQ Typical Cleanup Level (Table 1.1), lead based on USEPA (1996), all other Target Levels based on MDEQ RBSL "look-up" tables and a distance to receptor of 1,400 feet.

^{b/} µg/L = Micrograms per Liter.

^{c/} U = Analyte not detected above corresponding number.

^{d/} NA = Not available.

^{e/} >sol = greater than the maximum solubility possible.

TABLE 4
COMPARISON OF MAXIMUM SITE SOIL GAS CONCENTRATIONS
TO OSHA PERMISSIBLE EXPOSURE LIMITS
BX Service Station, Area of Concern A (ST-06)
Keesler AFB
Biloxi, Mississippi

Chemical	Maximum Detected Concentration (ppmv^{a/})	OSHA PEL (ppmv)^{b/}	Maximum Concentration Above PEL?
Benzene	ND	1	No
Toluene	.006 M ^{d/}	200	No
Ethylbenzene	0.020	100	No
Xylenes	0.041	100	No
TPH ^{e/}	1.943	-- ^{f/}	--

Notes:

^{a/} ppmv = Parts per million, volume per volume.

^{b/} Occupational Safety and Health Administration (NIOSH, 1997) 8-hour time-weighted average permissible exposure limit.

^{c/} ND = Not detected above reporting limits.

^{d/} M data qualifier indicates potential bias due to matrix interferences.

^{e/} TPH = Total petroleum hydrocarbons.

^{f/} "--" = No PEL available.

groundwater contaminated with lead), was used to evaluate the significance of the maximum detected groundwater lead concentration. The modeling results indicated that the impacts of lead in site media on potential future residents are not significant.

PERFORMANCE DATA AND DATA ASSESSMENT

Analytical data are compared to Tier 1 RBSLs in Tables 2 through 4. Temporal variations in soil contaminant concentrations from 1996 to 1998 (during which time the in-well DDC system was operational) are shown on Figure 2. Total BTEX concentrations measured at all site monitoring wells from 1988 to 1998 indicate substantial oscillation in dissolved BTEX concentrations at the plume core (MW8-3, MW8-4, MW8-5, and MWA-11) during this period have been measured. These oscillations can be attributed to groundwater table fluctuations and the operation of the interim remediation systems since May 1993. The total BTEX plume appears to have been relatively stable, as evidenced by consistent BTEX concentrations in downgradient well MWA-9. In addition, no BTEX concentrations have been detected in cross-gradient and downgradient wells MWA-6, MWA-7, MWA-8, MWA-10, MWA-10B, and MWA-13. Stable plume length indicates that the mass of BTEX input in the groundwater system in the source area is approximately equal to the mass of BTEX being removed via natural attenuation processes.

PERFORMANCE DATA QUALITY

An electronic Level III validation was performed on the February 1998 analytical results obtained from the fixed-base laboratories. Analytical results associated with non-compliant QC criteria were qualified appropriately.

COST OF THE TECHNOLOGY SYSTEM

PROCUREMENT PROCESS

Procurement involved selection of an analytical subcontractor. Bids were obtained from three qualified analytical laboratories, and the selected firm was Quanterra in Wheat Ridge, Colorado.

COST DATA

(Identify organization that provided cost data and whether cost data are actual or estimated costs)

Item	Cost (\$ Year Basis)	Actual or Estimated (A or E)
Capital (specify cost/activity) Bioventing	\$40,000	E
Operation and maintenance (specify cost/activity) LTM	\$15,000 (cost per event)	E
Other (specify)		

REGULATORY/INSTITUTIONAL ISSUES

Identify the approvals, licenses, and permits required to operate the technology at the site.

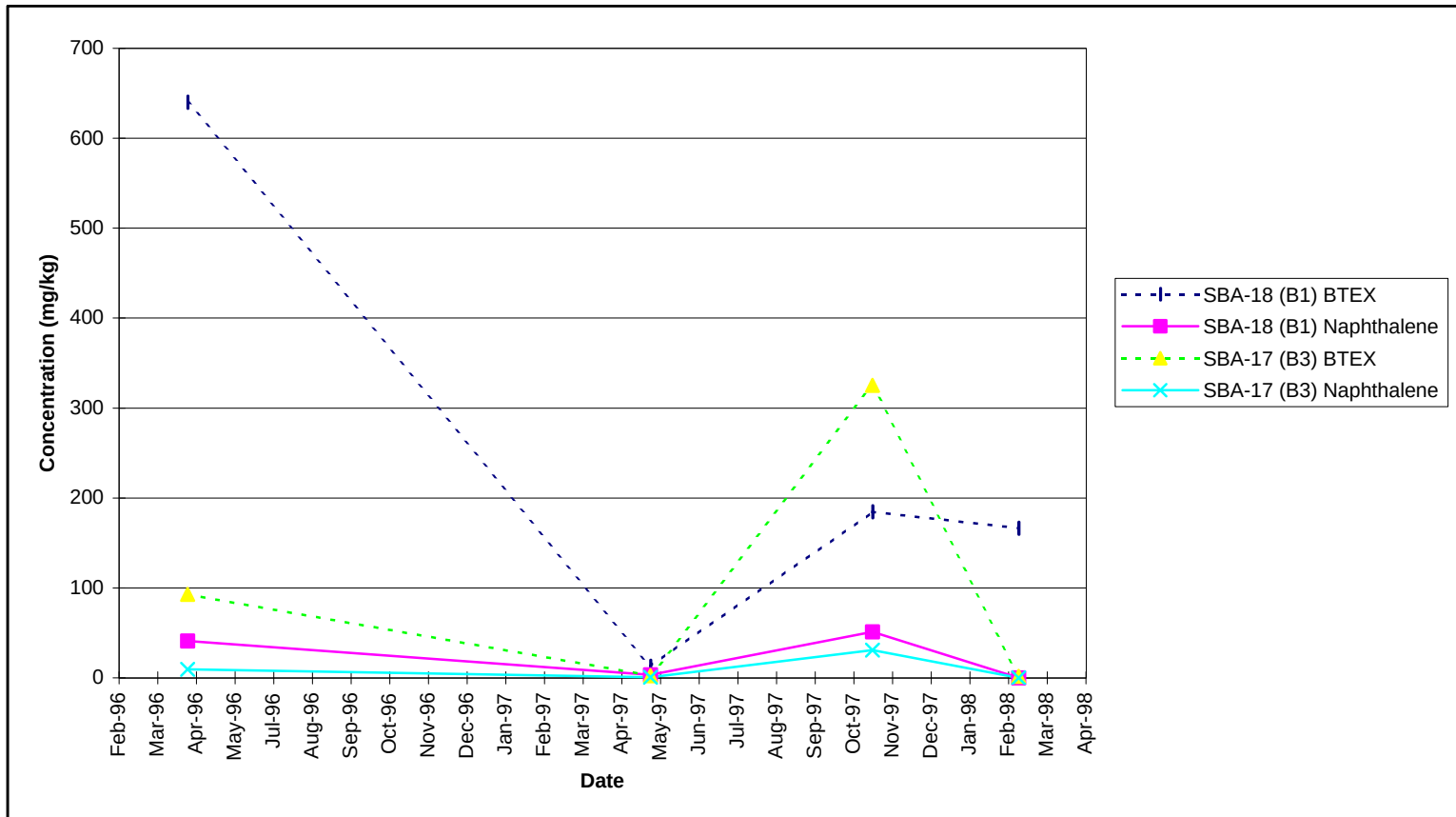
NA

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

(Provide only for demonstration-scale reports)

Identify technology applicability, competing technologies, and technology maturity; may also discuss commercialization and intellectual property issues.

FIGURE 2
HISTORICAL COMPARISON OF SOIL ANALYTICAL DATA
BX Service Station, Area of Concern A (ST-06)
Keesler AFB
Biloxi, Mississippi



Remediation by natural attenuation (RNA) is applicable for all petroleum-hydrocarbon contaminated sites. RNA is advantageous for the following reasons:

- Contaminants can be transformed to innocuous byproducts (e.g., carbon dioxide or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally no more effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA can be less costly than conventional, engineered remedial technologies.

A potential disadvantage of RNA is that, in some cases, natural attenuation rates are too slow to make RNA a practical remedial alternative.

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

Provide observations and lessons learned related to cost of the application.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

The following conclusions were drawn from the risk-based assessment of the site:

- Concentrations of target analytes in all sampled media do not exceed applicable MDEQ RBSLs or OSHA PELs, and detected concentrations of total lead in groundwater do not pose a risk to potential receptors;
- Geochemical data strongly indicate that biodegradation of fuel hydrocarbons is occurring at the site, primarily via the anaerobic processes of sulfate reduction, nitrogen fixation, and methanogenesis;
- Previous and current source removal efforts have reduced hydrocarbon concentrations in vadose zone and saturated zone soils, and the current system does not have an adverse effect on the natural attenuation processes at the site;
- Available data indicate that the dissolved plume is stable, is entirely contained within the existing monitoring well network, and should not impact potential downgradient receptors;
- Keesler AFB is an active base where institutional controls can be maintained with a high level of confidence; and
- None of the potential exposure pathways identified for the site are considered complete.

Per the above conclusions, monitored natural attenuation is appropriate for the BX Service Station.

OTHER OBSERVATIONS AND LESSONS LEARNED

A long-term monitoring plan was negotiated with the MDEQ and the USEPA Region IV that included monitoring of nine wells for five years. Monitoring will occur quarterly for the first year and annually for the second through fifth years. The purpose of the monitoring is to verify the effectiveness of naturally-occurring remediation processes at limiting plume migration and reducing dissolved contaminant concentrations.

The risk-based corrective action process performed for this site can be used to achieve cost-effective site closure at other relatively low-risk fuel-contaminated sites.

REFERENCES

List of references used in preparation of the cost and performance report.

USEPA, 1994a. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities.

USEPA, 1994b. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. Office of Emergency and Remedial Response. PEA 540-R-93-081.

ACKNOWLEDGMENTS

This case study report was prepared by Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, 303-831-8100. The report was prepared for Jim Gonzales at AFCEE/ERT under AETC Contract No. F41689-96-D-0710, Delivery Order 5015.

APPENDIX B

CASE STUDY 2 – KEESLER AFB

FORMER BUILDING 2093 GAS STATION

Kelly Air Force Base Former Building 2093 Gas Station

Site Name

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Former Building 2093 Gas Station, LPST ID No. 93205, Facility ID No. 0038825.

Location: Kelly AFB, Texas

CERCLIS ID No.: NA

Regulatory Context: Lead agency is the Petroleum Storage Tank (PST) Division of the Texas Natural Resource Conservation Commission (TNRCC).

TECHNOLOGY APPLICATION

Period of Performance: July 1997 – July 1998

Area of Contaminated Zone (source area plus dissolved plume): 1.5 acres

BACKGROUND

Waste Management Practice That Contributed to Contamination: Leaking gasoline USTs and associated piping.

Site History: Three MOGAS USTs were integrity tested in 1989, and one failed the test. The USTs and some associated piping were removed in 1991 and were not replaced. Multiple monitoring well installation and groundwater sampling events between 1989 and 1997 indicated the presence of groundwater contamination.

Remedy Selection: A 1-year-long bioventing pilot test was concluded in January 1995; the test results indicated that site soils were not sufficiently permeable to enable use of this in situ source reduction technique. Later in 1995, the dispensing islands and remaining below-grade piping were removed, and 2,750 cubic yards of soil in the area of the former tank pad and dispensing islands were excavated. Based on this RBCA analysis, the TNRCC issued a no-further-action memorandum closing the site based on plume stability, the documented occurrence of natural attenuation of fuel residuals, and the conclusion that site contamination does not currently (and will not in the future) pose a significant risk to potential receptors.

SITE LOGISTICS/CONTACTS

(Provide name, address, telephone, e-mail)

Site Lead: Mr. Jerry Arriaga, SA-ALC/EMRO, 301 Tinker Dr., Suite 2, Bldg. 301, Kelly AFB, TX 78241, (210) 925-1819, garriaga@emgate1.kelly.af.mil.

Oversight: Mr. Jim Gonzales, AFCEE/ERT, 3207 North Rd., Building 532, Brooks AFB, TX 78235-5363, (210) 536-4324, james.gonzales@hqafcee.brooks.af.mil.

Regulatory Contact: Mr. Antonio Pena, Texas Natural Resource Conservation Commission, P.O. Box 13087, Austin, TX, 78711-3087, (512) 239-2200, APENA@tnrcc.state.tx.us.

Prime Contractor: Mr. John Hicks, Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, (303) 831-8100, john.hicks@parsons.com

Additional Contacts: NA

MATRIX DESCRIPTION

MATRIX IDENTIFICATION

Type of Matrix Processed Through Technology System: RBCA study addressed soil, groundwater, and soil gas.

CONTAMINANT CHARACTERIZATION

Primary Contaminant Groups and Concentrations Measured During Site Investigation:

Gasoline constituents, see attached Figure 1 for distribution of BTEX in groundwater.

Contaminant Properties:

Based on a Tier 1 screening, only benzene in groundwater and soil was identified as a contaminant of potential concern at the former Building 2093 Gas Station. Benzene is volatile, highly soluble in water, and relatively mobile in the groundwater environment. It is also readily biodegradable under both aerobic and anaerobic conditions.

MATRIX CHARACTERISTICS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant parameters for the application)

Parameter	Value	Measurement Procedure
Soil Classification	NA	NA
Clay Content and/or Particle Size Distribution	NA	NA
Additional Soil Characteristics (specify)	NA	NA

SITE GEOLOGY/STRATIGRAPHY/HYDROGEOLOGY

Describe heterogeneity, depth to groundwater, size and characteristics of applicable aquifers and units (especially important for in situ technologies)

The site is underlain by silty clay. A distinct clay unit approximately 3 to 5 feet thick is evident from 35 to 40 feet below ground surface (bgs). Groundwater occurs primarily in silt and possibly caliche seams that produce only small amounts of water. Boreholes that do not intercept one or more water-bearing zones do not yield water. Static groundwater levels range from 5 to 25 feet bgs, depending on location and season. The hydraulic conductivity of the silty clay unit is 0.2 to 0.5 ft/day based on slug tests, and the estimated horizontal groundwater flow velocity is 31 ft/year.

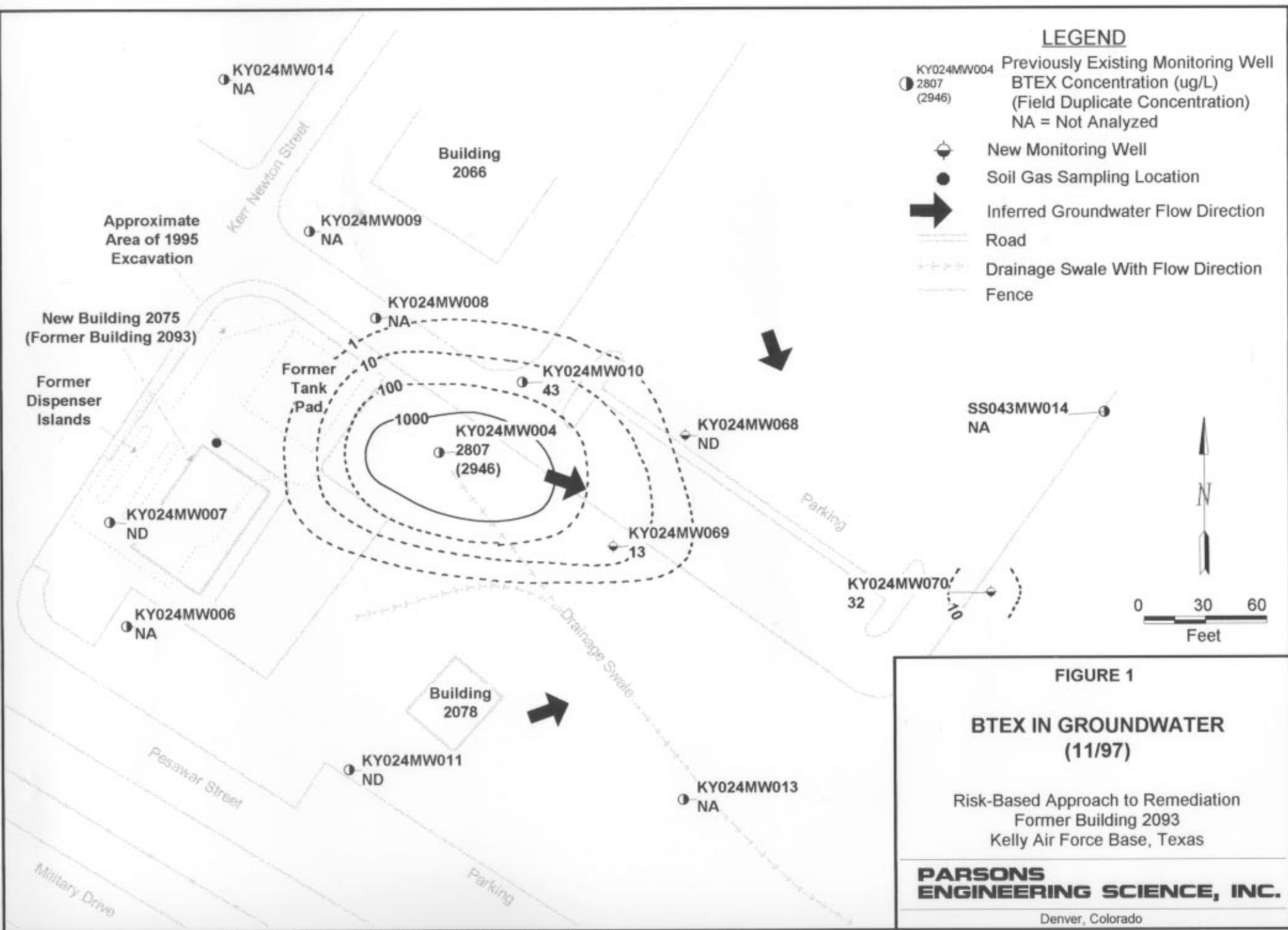
TECHNOLOGY SYSTEM DESCRIPTION

PRIMARY TECHNOLOGY

Monitored natural attenuation

SUPPLEMENTAL TECHNOLOGY TYPES

Soil excavation



REMEDIATION SYSTEM DESCRIPTION AND OPERATION

Fate and transport modeling using the analytical code BIOSCREEN (Newell *et al.*, 1996) indicated that the maximum migration distance of dissolved benzene from the source area will be approximately 300 feet, and that dissolved benzene concentrations will be below groundwater quality standards within 10 years. Therefore, the site is a candidate for immediate closure according to TNRCC guidance. The Air Force will restrict use of the shallow groundwater at the site until all dissolved benzene concentrations decrease below TNRCC Plan A Category II criterion of 0.0294 mg/L.

OPERATING PARAMETERS AFFECTING TECHNOLOGY COST OR PERFORMANCE

(Provide information on relevant operating parameters for the application.)

Parameter	Value
Example: Temperature	NA
Others (as appropriate)	NA

TIMELINE

(Provide dates for key activities for the application, focusing on events related to technology.)

Start Date	End Date	Activity
July 1997	July 1997	Kickoff Meeting
August 1997	Nov. 1997	Project Work Plan (draft and final)
Nov. 1997	Nov. 1997	Field Site Characterization
Dec. 1997	July 1998	Data Analysis and Corrective Action Plan (draft and final)
	June 1998	Site Closure by TNRCC

TECHNOLOGY SYSTEM PERFORMANCE

CLEANUP GOALS/STANDARDS

The groundwater beneath the site is designated as Category II (TDS concentration of affected groundwater is less than 3,000 mg/L and no beneficial use is documented within 0.5 mile of the site, or the TDS is between 3,000 and 10,000 mg/L and beneficial use is documented within 0.5 mile of the site). The TNRCC (1994) Plan A target concentrations for Category II aquifers, and the TNRCC (1997) target concentrations for construction worker exposure are the cleanup goals for affected groundwater. Only the Plan A concentration for benzene of 0.0294 mg/L was exceeded.

Maximum-detected concentrations of BTEX in soil gas were compared to the chemical-specific OSHA 8-hour time-weighted average permissible exposure limits (PELs), and there were no exceedences.

PERFORMANCE DATA AND DATA ASSESSMENT

Results of previous groundwater sampling events indicate that the dissolved contaminant plume is not increasing in areal extent. Natural attenuation indicator parameters exhibit trends associated with a plume which is being naturally degraded. Because the source is mostly removed (prior excavation of contaminated soils), biodegradation will continue to decrease the concentrations of dissolved contaminants. Assimilative capacity calculations suggest that the shallow groundwater has the biological capacity to attenuate the existing contamination. BIOSCREEN modeling results indicate that the dissolved plume will not migrate off-site at levels above TNRCC criteria, and benzene concentrations should decrease below the cleanup goal within 10 years.

PERFORMANCE DATA QUALITY

An electronic Level III validation was performed on the February 1998 analytical results obtained from the fixed-base laboratories. Analytical results associated with non-compliant QC criteria were qualified appropriately.

COST OF THE TECHNOLOGY SYSTEM**PROCUREMENT PROCESS**

Procurement involved selection of an analytical subcontractor. Bids were obtained from three qualified analytical laboratories, and the selected firm was Quanterra in Wheat Ridge, Colorado.

COST DATA

(Identify organization that provided cost data and whether cost data are actual or estimated costs)

Item	Cost (\$ Year Basis)	Actual or Estimated (A or E)
Capital (specify cost/activity)	NA	NA
Operation and maintenance (specify cost/activity)	NA	NA
Other (specify)	NA	NA

REGULATORY/INSTITUTIONAL ISSUES

Identify the approvals, licenses, and permits required to operate the technology at the site.

NA

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Identify technology applicability, competing technologies, and technology maturity; may also discuss commercialization and intellectual property issues.

Remediation by natural attenuation (RNA) is applicable for all petroleum-hydrocarbon contaminated sites. RNA is advantageous for the following reasons:

- Contaminants can be transformed to innocuous byproducts (e.g., carbon dioxide or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally no more effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA can be less costly than conventional, engineered remedial technologies.

A potential disadvantage of RNA is that, in some cases, natural attenuation rates are too slow to make RNA a practical remedial alternative.

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

Provide observations and lessons learned related to cost of the application.

No costs will be incurred due to regulatory site closure.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

The following conclusions were drawn from the risk-based assessment of the site:

Given the low potential for current or future exposure to site contaminants, the historical groundwater data which indicates a contaminant plume that is not increasing in areal extent, and the strong geochemical evidence that natural attenuation is occurring at the site, Former Building 2093 is a candidate for immediate closure according to TNRCC guidance. Given the fact that dissolved benzene concentrations in groundwater remain above TNRCC Plan A Category II criteria near the source area, Kelly AFB proposes to restrict use of the shallow groundwater at the site.

OTHER OBSERVATIONS AND LESSONS LEARNED

The risk-based corrective action program administered by the PST Division of the TNRCC allows for rapid site closure if the groundwater contaminant plume is stable or declining in magnitude and/or size, the beneficial impacts of natural attenuation can be documented, and the potential for current or future exposure of receptors to site contamination is low. The risk-based corrective action process performed for this site can be used to achieve cost-effective site closure at other relatively low-risk fuel-contaminated sites.

List of references used in preparation of the cost and performance report.

REFERENCES

Newell, C.J., Mcleod, R.K., and Gonzales, J.R. 1996. *Bioscreen Natural Attenuation Design Support System User's Manual*, Version 1.3. Prepared for the Environmental Services Office, Air Force Center for Environmental Excellence (AFCEE) by Groundwater Services, Inc. June.

TNRCC. 1997c. Target Concentrations for Construction Worker Exposures. Facsimile from Vicki Montgomery at TNRCC Petroleum Storage Tank Division. Extracted from the March 6, 1997 TNRCC memorandum Clarifications and Amendments for Implementation of RG-36. July 24.

TNRCC. 1994. Risk-Based Corrective Action for Leaking Underground Storage Tank Sites. RG-36. January.

ACKNOWLEDGMENTS

This case study report was prepared by Parsons Engineering Science, Inc., 1700 Broadway, Suite 900, Denver, CO 80290, 303-831-8100. The report was prepared for Jim Gonzales at AFCEE/ERT under AETC Contract No. F41689-96-D-0710, Delivery Order 5015.

APPENDIX C

SUMMARY DATA TABLE

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Final Report Date	Current or Prior Engineered Remediation ^{b/}	Soil COPCs ^{a/}		
				Benzene	Ethylbenzene	Xylenes
Eglin AFB, FL	Seventh Street Service Station	March-1999	GE, BV	-- ^{c/}	X ^{d/}	X
Eglin AFB, FL	Military Gas Station	March-1999	AS, SVE	--	--	--
Kelly AFB, TX	Former Building 2093 Gas Station	July-1998	Soil Excavation	X	--	--
Randolph AFB, TX	BX Service Station	May-1998	NA ^{e/}	--	--	--
Keesler AFB, MS	BX Service Station	April-1999	DDC	--	--	--
Tyndall AFB, FL	BX Service Station	August-1999	NA	X	--	--
Tyndall AFB, FL	FT-16	August-1999	NA	--	--	--
Seymour Johnson AFB, NC	Building 4522	July-1999	PR	--	--	--
Pope AFB, NC	ST-08	September-1999	BV	--	--	--

Air Force Facility	Site	Maximum Soil COPC Concentration (mg/kg) ^{f/}		
		Benzene	Ethylbenzene	Xylenes
Eglin AFB, FL	Seventh Street Service Station	--	710	1400
Eglin AFB, FL	Military Gas Station	--	--	--
Kelly AFB, TX	Former Building 2093 Gas Station	2.7	--	--
Randolph AFB, TX	BX Service Station	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--
Tyndall AFB, FL	BX Service Station	<2.4	--	--
Tyndall AFB, FL	FT-16	--	--	--
Seymour Johnson AFB, NC	Building 4522	--	--	--
Pope AFB, NC	ST-08	--	--	--

^{a/} COPC = Chemical of potential concern.

^{b/} GE = Groundwater extraction, BV = Bioventing, AS = Air Sparging, SVE = Soil vapor extraction, DDC = Density-driven convection, PR = Product recovery.

^{c/} "--" indicates that the contaminant was not a COPC.

^{d/} "X" = The contaminant was a COPC.

^{e/} NA = Not analyzed.

^{f/} mg/kg = Milligrams per kilogram.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Groundwater COPCs ^{a/}					
		Benzene	Toluene	Ethylbenzene	Xylenes	Lead	Total Lead
Eglin AFB, FL	Seventh Street Service Station	X ^{b/}	X	X	X	-- ^{c/}	X
Eglin AFB, FL	Military Gas Station	--	--	X	X	X	--
Kelly AFB, TX	Former Building 2093 Gas Station	X	--	--	--	--	--
Randolph AFB, TX	BX Service Station	X	--	--	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--	--	--	X
Tyndall AFB, FL	BX Service Station	X	X	X	X	X	--
Tyndall AFB, FL	FT-16	X	--	X	X	--	--
Seymour Johnson AFB, NC	Building 4522	--	--	--	--	--	--
Pope AFB, NC	ST-08	--	--	--	--	--	--

Air Force Facility	Site	Groundwater COPCs (Continued)				
		TRPH ^{d/}	Naphthalene	MTBE ^{e/}	Benzo(b)fluoranthene	Benzo(k)fluoranthene
Eglin AFB, FL	Seventh Street Service Station	X	X	--	--	--
Eglin AFB, FL	Military Gas Station	--	X	--	--	--
Kelly AFB, TX	Former Building 2093 Gas Station	--	--	--	--	--
Randolph AFB, TX	BX Service Station	--	--	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--	--	--
Tyndall AFB, FL	BX Service Station	X	X	X	--	--
Tyndall AFB, FL	FT-16	X	--	--	--	--
Seymour Johnson AFB, NC	Building 4522	--	--	--	--	--
Pope AFB, NC	ST-08	--	--	--	X	X

^{a/} COPC = Chemical of potential concern.

^{b/} "X" = The contaminant was a COPC.

^{c/} "--" indicates that the contaminant was not a COPC.

^{d/} TRPH = Total recoverable petroleum hydrocarbons.

^{e/} MTBE = Methyl tertiary butyl ether.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Maximum Groundwater COPC ^{a/} Concentration (µg/L) ^{b/}							
		Benzene	Toluene	Ethylbenzene	Xylenes	Lead	Total Lead	TRPH ^{c/}	Naphthalene
Eglin AFB, FL	Seventh Street Service Station	86	11000	1600	13000	--	19	38000	510
Eglin AFB, FL	Military Gas Station	-- ^{d/}	--	76	400	19	--	--	40
Kelly AFB, TX	Former Building 2093 Gas Station	2200	--	--	--	--	--	--	--
Randolph AFB, TX	BX Service Station	7.1	--	--	--	--	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--	--	--	21	--	--
Tyndall AFB, FL	BX Service Station	3400	5000	3100	16000	62	--	41000	320
Tyndall AFB, FL	FT-16	71	--	44	39	--	--	7.1	--
Seymour Johnson AFB, NC	Building 4522	--	--	--	--	--	--	--	--
Pope AFB, NC	ST-08	--	--	--	--	--	--	--	--

Air Force Facility	Site	Maximum Groundwater COPC Concentration (µg/L) Continued			Soil Gas COPCs			Maximum Soil Gas COPC Concentration (ppmv) ^{e/}		
		MTBE ^{f/}	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzene	Toluene	Xylenes	Benzene	Toluene	Xylenes
Eglin AFB, FL	Seventh Street Service Station	--	--	--	--	--	--	--	--	--
Eglin AFB, FL	Military Gas Station	--	--	--	--	--	--	--	--	--
Kelly AFB, TX	Former Building 2093 Gas Station	--	--	--	--	--	--	--	--	--
Randolph AFB, TX	BX Service Station	--	--	--	--	--	--	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--	--	--	--	--	--	--
Tyndall AFB, FL	BX Service Station	1300	--	--	X ^{g/}	--	--	24	--	--
Tyndall AFB, FL	FT-16	--	--	--	--	--	--	--	--	--
Seymour Johnson AFB, NC	Building 4522	--	--	--	X	X	X	260	59	110
Pope AFB, NC	ST-08	--	1	0.7	--	--	--	--	--	--

^{a/} COPC = Chemical of potential concern.

^{b/} µg/L = Micrograms per liter.

^{c/} TRPH = Total recoverable petroleum hydrocarbons.

^{d/} "--" indicates that the contaminant was not a COPC.

^{e/} ppmv = parts per million by volume.

^{f/} MTBE = Methyl tertiary butyl ether.

^{g/} "X" = The contaminant was a COPC.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Historical Reductions in Contaminant Concentrations	
		Soil	Groundwater
Eglin AFB, FL	Seventh Street Service Station	Substantial reductions in vadose zone since 1992	Decreasing levels since 1994
Eglin AFB, FL	Military Gas Station	Substantial reductions in vadose zone since 1994	Decreasing levels since 1992
Kelly AFB, TX	Former Building 2093 Gas Station	NA ^{a/}	Oscillating up and down
Randolph AFB, TX	BX Service Station	NA	Oscillating up and down
Keesler AFB, MS	BX Service Station	Substantial reductions since 1992	Oscillating up and down
Tyndall AFB, FL	BX Service Station	Overall decrease since 1995	Variable, but stable to decreasing from 1997 to 1998
Tyndall AFB, FL	FT-16	Overall decrease since 1995	Consistent decrease since 1995
Seymour Johnson AFB, NC	Building 4522	Substantial reduction since 1996	Decrease since 1996
Pope AFB, NC	ST-08	Substantial reduction since 1995	Decrease since 1997

Air Force Facility	Site	Calculated Biodegradation rate (day ⁻¹)					
		BTEX ^{b/}	Benzene	Toluene	Ethylbenzene	Xylenes	Naphthalene
Eglin AFB, FL	Seventh Street Service Station	0.006-0.01	-- ^{c/}	--	--	--	--
Eglin AFB, FL	Military Gas Station	--	--	--	0.001	--	0.0007
Kelly AFB, TX	Former Building 2093 Gas Station	--	0.002	--	--	--	--
Randolph AFB, TX	BX Service Station	--	0.003-0.004	--	--	--	--
Keesler AFB, MS	BX Service Station	--	--	--	--	--	--
Tyndall AFB, FL	BX Service Station	--	0.0067	0.017	0.0059	0.0073	--
Tyndall AFB, FL	FT-16	--	0.0052	0.0027	0.006	0.0033	--
Seymour Johnson AFB, NC	Building 4522	0.0026	0.0049	--	--	--	--
Pope AFB, NC	ST-08	--	--	--	--	--	--

^{a/} NA = Data not available.

^{b/} BTEX = Benzene, toluene, ethylbenzene, and xylenes.

^{c/} "--" indicates that a biodegradation rate was not calculated.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Groundwater Assimilative Capacity (mg/L) ^{a/}								
		BTEX ^{b/}	Benzene	Toluene	Ethylbenzene	Xylenes	Naphthalene	MTBE ^{c/}	Benzo(b)fluoranthene	Benzo(k)fluoranthene
Eglin AFB, FL	Seventh Street Service Station	-- ^{d/}	13.1	12.9	12.7	12.7	13.4	--	--	--
Eglin AFB, FL	Military Gas Station	--	--	--	12.6	12.6	13.2	--	--	--
Kelly AFB, TX	Former Building 2093 Gas Station	--	12.5	--	--	--	--	--	--	--
Randolph AFB, TX	BX Service Station	--	13-20.4	--	--	--	--	--	--	--
Keesler AFB, MS	BX Service Station	11.2	--	--	--	--	--	--	--	--
Tyndall AFB, FL	BX Service Station	--	16.6	16.3	16.1	16.1	16.7	18.5	--	--
Tyndall AFB, FL	FT-16	--	3.96	--	3.85	3.85	--	--	--	--
Seymour Johnson AFB, NC	Building 4522	--	3.27	3.22	3.18	3.18	2.97	--	--	--
Pope AFB, NC	ST-08	--	9.49	9.32	9.22	9.22	9.6	--	9.86	9.86

Air Force Facility	Site	Number of Plumes	Estimated Plume Stability Based on Groundwater Quality	BIOSCREEN Modeling Results - Simulated Migration Relative to Measured Plume		
				Compound Simulated	1st Order Routine	Instantaneous Reaction Routine
Eglin AFB, FL	Seventh Street Service Station	1	Hydraulically Controlled	Xylenes	Additional 130 ft	Additional 690 ft
Eglin AFB, FL	Military Gas Station	1	Receding	NA ^{e/}	NA	NA
Kelly AFB, TX	Former Building 2093 Gas Station	1	Stable	Benzene	Additional 150 ft	NA
Randolph AFB, TX	BX Service Station	2	Stable(1), ND ^{f/} (2)	Benzene	Receding (1), ND (2)	Additional 80-180 ft (1), ND
Keesler AFB, MS	BX Service Station	1	Stable	NA	NA	NA
Tyndall AFB, FL	BX Service Station	2	Stable (1), Receding (2)	Benzene + Xylenes	NA	Both receding
Tyndall AFB, FL	FT-16	1	Stable to Receding	Benzene	ND	NA
Seymour Johnson AFB, NC	Building 4522	1	Expanding	Benzene	Additional 230 ft	NA
Pope AFB, NC	ST-08	1	ND	Benzene	NA	Additional 150 ft

^{a/} mg/L = Milligrams per liter.

^{b/} BTEX = Benzene, toluene, ethylbenzene, and xylenes.

^{c/} MTBE = Methyl tertiary butyl ether.

^{d/} "--" indicates that an assimilative capacity was not calculated.

^{e/} NA = Not applicable.

^{f/} ND = Not determined.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	BIOSCREEN Modeling Results (Continued)			
		Simulated Effects of 80% Source Removal		Simulated Persistence of COPC ^{a/} Above Tier 1 RBSL ^{b/}	
		Predicted Migration			
		1st Order Routine	Instantaneous Reaction Routine	1st Order Routine	Instantaneous Reaction Routine
Eglin AFB, FL	Seventh Street Service Station	Additional 130 ft	Additional 340 ft	>1000 µg/L for >400 yr	150 yr
Eglin AFB, FL	Military Gas Station	NA ^{c/}	NA	NA	NA
Kelly AFB, TX	Former Building 2093 Gas Station	NA	NA	10 yr	5 yr
Randolph AFB, TX	BX Service Station	NA	NA	>13 yr	8 yr
Keesler AFB, MS	BX Service Station	NA	NA	NA	NA
Tyndall AFB, FL	BX Service Station	NA	Both Receding Faster	NA	20-69 yr
Tyndall AFB, FL	FT-16	NA		7 yr	1 yr
Seymour Johnson AFB, NC	Building 4522	NA	NA	ND ^{d/}	ND
Pope AFB, NC	ST-08	NA	NA	ND	ND

Air Force Facility	Site	Tier 2 Chemicals of Concern (COCs) ^{e/}			
		Groundwater COCs	Soil Gas COCs	Soil COCs	Surface Water COCs
Eglin AFB, FL	Seventh Street Service Station	None	None	None	NA
Eglin AFB, FL	Military Gas Station	None	None	None	NA
Kelly AFB, TX	Former Building 2093 Gas Station	None	None	None	NA
Randolph AFB, TX	BX Service Station	None	None	None	NA
Keesler AFB, MS	BX Service Station	None	None	None	NA
Tyndall AFB, FL	BX Service Station	Benzene	None	None	NA
Tyndall AFB, FL	FT-16	None	None	None	NA
Seymour Johnson AFB, NC	Building 4522	None	Benzene	None	NA
Pope AFB, NC	ST-08	None	None	None	None

^{a/} COPC = Chemical of potential concern.

^{b/} RBSL = Risk based screening level.

^{c/} NA = Not applicable.

^{d/} ND = Not determined.

^{e/} COC = Chemical of concern with concentration exceeding Tier 2 site-specific target level.

SUMMARY DATA TABLE
STREAMLINED RBCA SITE CLOSURE PROJECT

Air Force Facility	Site	Risk Assessment Results	Remediation Alternatives Considered	Number of LTM ^{b/} Wells Proposed	Recommended LTM Duration (yr)	Recommended LTM Frequency
		Potential, Current or Future Risk to Receptors?				
Eglin AFB, FL	Seventh Street Service Station	No	MNA + IC, BS + SVE, GE + SVE	6	30	Semiannual for 5 yrs, then biennial for 25 yrs
Eglin AFB, FL	Military Gas Station	No	MNA + IC	4	9	Annual for 3 yrs, then biennial for 6 yrs
Kelly AFB, TX	Former Building 2093 Gas Station	No	MNA + IC	0	0	NA
Randolph AFB, TX	BX Service Station	No	MNA + IC + BV	11	2	Semiannual
Keesler AFB, MS	BX Service Station	No	MNA + IC	9	5	Quarterly for 1 yr, then annual for 4 yrs.
Tyndall AFB, FL	BX Service Station	Yes- Future onsite intrusive workers	MNA + IC, MNA + IC + BS + SVE	8	3	Annual
Tyndall AFB, FL	FT-16	No	MNA	5	3	Annual
Seymour Johnson AFB, NC	Building 4522	Yes- Future indoor receptors from inhalation of benzene	MNA + IC + PR	0	0	NA
Pope AFB, NC	ST-08	No	NA ^{c/}	ND	NA	NA

Air Force Facility	Site	Remedial Alternative Costs	Recommendation
Eglin AFB, FL	Seventh Street Service Station	\$270,000, \$490,000, \$540,000	BS+SVE or GE+SVE
Eglin AFB, FL	Military Gas Station	ND ^{d/}	Closure contingent on LTM
Kelly AFB, TX	Former Building 2093 Gas Station	ND	Closure
Randolph AFB, TX	BX Service Station	ND	Closure contingent on LTM
Keesler AFB, MS	BX Service Station	ND	Closure contingent on LTM
Tyndall AFB, FL	BX Service Station	\$214,000, \$505,000	MNA to SSTLs then inactive but managed status
Tyndall AFB, FL	FT-16	ND	Closure contingent on LTM
Seymour Johnson AFB, NC	Building 4522	ND	Continue product recovery, then close based on low risk
Pope AFB, NC	ST-08	ND	ND

^{a/} MNA = Monitored natural attenuation, IC = Institutional controls, BS = Biosparging, GE = Groundwater extraction, BV = Bioventing, SVE = Soil vapor extraction, DDC = Density-driven convection, PR = Product recovery.

^{b/} LTM = Long-term monitoring

^{c/} NA = Not applicable.

^{d/} ND = Not determined.