FINAL
FEASIBILITY STUDY
LHAAP-67, ABOVEGROUND STORAGE TANK FARM, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

Prepared for

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Acronyms and Abbreviations

μg	micrograms
AOC	area of concern
ARARs	applicable or relevant and appropriate requirements
Army	U.S. Department of the Army
AWQC	ambient water quality criteria
BERA	baseline ecological risk assessment
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COCs	contaminants of concern
COPCs	contaminants of potential concern
CWA	Clean Water Act of 1972
DCA	dichloroethane
DCE	dichloroethene
ELCR	excess lifetime cancer risk
°F	degrees Fahrenheit
FFA	Federal Facility Agreement
FS	feasibility study
GAC	granulated activated carbon
GRAs	general response actions
HI	hazard index
HQ	hazard quotient
HRC®	Hydrogen Release Compound®
kg	kilogram
L	liter
LHAAP	Longhorn Army Ammunition Plant
MCLGs	maximum contaminant level goals
MCLs	maximum contaminant levels
mg	milligram
MNA	monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
pH	hydrogen ion concentration

Acronyms and Abbreviations (continued)

RAOs	remedial action objectives
RfDs	cancer risks and reference doses
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of decision
SVOC	semivolatile organic compound
TAC	Texas Administrative Code
TBC	to-be-considered
TCA	trichloroethane
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
TNRCC	Texas Natural Resources Conservation Commission
USACE	U.S. Army Corps of Engineers
USC	United States Code
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
ZVM	zero-valence metals

Executive Summary

This Feasibility Study (FS) was prepared by Shaw Environmental, Inc. for the U.S. Army Corps of Engineers (USACE), Tulsa District, under Total Environmental Restoration Contract DACA56-94-D-0020, Task Order 0109, and presents an analysis of remedial approaches for the Aboveground Storage Tank Farm, designated LHAAP-67, a Group 4 site at the former Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. This FS for LHAAP-67 was developed based on a Draft FS for the Group 4 Sites (Jacobs Engineering Group [Jacobs], 2002a), and provides a basis for remedy selection consistent with the intended future use of LHAAP as a wildlife refuge.

LHAAP is an inactive, government-owned, formerly contractor-operated and maintained Department of Defense facility located in central-east Texas. The entire installation was under the control of the U.S. Department of the Army (Army) until May 05, 2004, when approximately two thirds of the property was transferred to the U.S. Department of Interior's Fish and Wildlife Service (USFWS). The U.S. Army Environmental Center has the responsibility for the environmental restoration activities at LHAAP, with the management of the Army's property provided by the Base Realignment and Closure Office. The Group 4 Sites at LHAAP are currently inactive and consist primarily of previous industrial areas used for or supporting, the production of 2,4,6-trinitrotoluene and rocket motors. The installation's groundwater, surface water, sediment, and soil have been contaminated by past operations. LHAAP-67 was a 1.91-acre area that consisted of seven aboveground storage tanks. Site personnel indicate that the tanks were used for solvent storage. The tanks have since been removed and no structures remain at the site with the exception of a railroad bed.

The nearest significant surface water body to LHAAP-67 is Central Creek located approximately 500 feet southeast of the site. Runoff from LHAAP-67 eventually drains into Caddo Lake (a drinking water source for multiple communities) via Central Creek.

Phase I through Phase III Remedial Investigations (RIs) and supplemental RIs were conducted by Jacobs at the Group 4 sites. Sampling specific to the LHAAP-67 media was conducted during the Phase III RI in 1998 and 2000. The baseline human health risk assessment for the Group 4 Sites (Jacobs, 2003), which was based on data from the RIs, determined that the groundwater at LHAAP-67 poses an unacceptable cancer risk and non-cancer hazard for a future maintenance worker under an industrial scenario. Approximately 98 percent of the total cancer risk in groundwater was contributed by 1,1-dichloroethene (DCE). Site contamination was likely due to releases from the tanks formerly located at the site.

A remedial action objective (RAO) has been established within this FS to address contamination associated with LHAAP-67. The RAO does not address potential ecological issues because the installation-wide ecological risk assessment is not yet complete. The RAO for LHAAP-67, which takes into account the future use of the site as a wildlife refuge, is to prevent exposure to contaminated groundwater in excess of the 1×10^{-4} to 1×10^{-6} target cancer risk range and non-cancer hazard index (HI) of 1 for the future maintenance worker, and to prevent potential site groundwater impacts to nearby surface water bodies such that applicable or relevant and appropriate requirements (ARARs) are met.

This FS identifies principal contaminants of concern (COCs) associated with LHAAP-67 groundwater to be addressed in order to satisfy the RAO for the site. Groundwater with an unacceptable risk is present at LHAAP-67, primarily due to 1,1-DCE. The following contaminants were also detected in groundwater at concentrations exceeding their respective maximum contaminant levels (MCLs): 1,1-DCE, 1,2-dichloroethane (DCA), 1,1,1-trichloroethane (TCA), 1,1,2-TCA and trichloroethene (TCE). All five of these aforementioned contaminants are considered COCs within this FS because they exceed their respective MCLs in groundwater. Additionally, the COCs present in groundwater beneath LHAAP-67 could also potentially discharge to surface water in Central Creek located to the southeast of the site, which flows to Caddo Lake. Although plume migration modeling indicates that the COCs in groundwater would not discharge to surface water at such levels that ARARs are exceeded within Central Creek, the potential for groundwater impact to surface water is addressed within this FS.

The FS identifies and screens remedial technologies and associated process options that may be appropriate for satisfying the RAO for LHAAP-67 with respect to effectiveness, implementability, and cost. Select remedial technologies and process options were carried forward after the initial screening and were combined to develop the following remedial alternatives for LHAAP-67:

- **Alternative 1 – No Action.** Leaves the contaminated groundwater in place with no remedial action or additional measures to prevent exposure to the COCs, and serves as a baseline for comparison with the other alternatives.
- **Alternative 2 – Land Use Controls.** Implements land use controls to prevent human exposure to contaminated groundwater, and through monitoring, verifies that COCs in groundwater do not impact nearby surface water bodies above acceptable levels.
- **Alternative 3 – In-Situ Bioremediation, Land Use Controls (Short Term).** Reduces contamination throughout the groundwater contaminant plume via in-situ bioremediation to levels that would allow future unrestricted reuse of the site. Implements short-term land use controls to prevent human exposure

to groundwater contaminants until such time that the remediation levels are met through treatment.

- **Alternative 4 – Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (Short Term).** Reduces contamination throughout the groundwater contaminant plume via groundwater extraction to levels that would allow future unrestricted reuse of the site. Implements short-term land use controls to prevent human exposure to groundwater contaminants until such time that the remediation levels are met.

Each of the alternatives was evaluated against Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria to provide a basis for selecting a preferred alternative in the follow-on Proposed Plan and Record of Decision documents.

Table ES-1 summarizes the comparative analysis of the alternatives presented in this study.

Table ES-1
Comparative Analysis of Alternatives

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 In-Situ Bioremediation, Land Use Controls (Short Term)	Alternative 4 Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (Short Term)
Overall protection of human health and the environment	No protection. Does not achieve RAO.	Achieves RAO. Protection of human health and environment provided by maintenance of land use controls. Monitoring activities would demonstrate that surface water is not impacted by groundwater contaminants.	Achieves RAO. Protection of human health and environment provided by remediation of groundwater COCs to MCLs. Protection of surface water provided by groundwater restoration.	Achieves RAO. Protection of human health and environment provided by remediation of groundwater COCs to MCLs. Protection of surface water provided by groundwater restoration.
Compliance with ARARs	No compliance with chemical-specific ARARs.	Does not comply with chemical-specific ARARs in groundwater. Complies with location- and action-specific ARARs.	Complies with all ARARs.	Complies with all ARARs.
Long-term effectiveness and permanence	Not effective.	Land use controls would be effective and reliable so long as they are maintained indefinitely.	Should be effective and permanent; however, uncertainty exists concerning the effectiveness of in-situ biological treatment for reducing groundwater contaminant concentrations to remediation levels. Treatability and pilot studies would be required to further assess the effectiveness of this treatment method.	Should be effective and permanent, but uncertainty exists whether groundwater extraction would sufficiently lower contaminant concentrations to remediation levels. A pre-design study would be required to determine the optimum extraction technique/configuration.
Reduction of toxicity, mobility, or volume through treatment	No reduction.	No active reduction would be accomplished.	Provides permanent and irreversible reduction only if the results of biological treatability and pilot studies prove favorable.	Extraction and treatment of contaminated groundwater reduces toxicity, mobility, and volume of groundwater contaminants in this area.
Short-term effectiveness	No short-term impacts.	Minimal impacts to the community, workers, or the environment from short-term activities. Provides almost immediate protection.	Minimal impacts to the community, workers, or the environment from short-term activities.	Minimal impacts to the community, workers, or the environment from short-term activities.

Table ES-1 (*continued*)
Comparative Analysis of Alternatives

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 In-Situ Bioremediation, Land Use Controls (Short Term)	Alternative 4 Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (Short Term)
Implementability	Inherently implementable.	Readily implemented.	Implementable, but uncertainty exists whether in-situ bioremediation would sufficiently lower contaminant concentrations to remediation levels. Further studies would be required. Specialized knowledge required for implementation.	Implementation straightforward, but uncertainty exists whether groundwater extraction would sufficiently lower contaminant concentrations to remediation levels. A pre-design study would be required.
Cost*				
• Capital	$0	$44,000	$1,580,000	$1,120,000
• O&M	$0	$364,000	$344,000	$1,550,000
Estimated Duration** (years)	—	30	6	30
• Present worth	$0	$221,000	$1,680,000	$1,740,000

Notes and Abbreviations:

* *Costs have been rounded to three significant figures.*

** *Estimated duration used for the purposes of cost comparison within this FS. Land Use Controls (Alternative 2) will likely be required indefinitely and groundwater extraction (Alternative 4) will likely be required beyond the 30 year period. In-situ bioremediation (Alternative 3) is expected to achieve the Remedial Goal Options within 6 years, but must be confirmed with a pilot study.*

ARAR	*applicable or relevant and appropriate requirement*
FS	*feasibility study*
LHAAP	*Longhorn Army Ammunition Plant*
MCL	*maximum contaminant level*
NA	*not applicable*
O&M	*operation and maintenance*
RAO	*remedial action objective*
VOC	*volatile organic compound*

1.0 Introduction

This Feasibility Study (FS) was prepared by Shaw Environmental, Inc., for the U.S. Army Corps of Engineers (USACE), Tulsa District, under Total Environmental Restoration Contract DACA56-94-D-0020, Task Order 0109, and presents an analysis of remedial alternatives for the Aboveground Storage Tank Farm, designated LHAAP-67, a Group 4 site at the former Longhorn Army Ammunition Plant (LHAAP), Karnack, Texas. A Draft FS for the Group 4 sites (Jacobs, 2002a) was used to develop this FS for LHAAP-67. This FS supersedes the Draft FS for the Group 4 sites in its discussion of LHAAP-67 and provides a basis for remedy selection consistent with the intended future use of LHAAP as a wildlife refuge.

LHAAP is an inactive, government-owned, formerly contractor-operated and maintained Department of Defense facility located in central-east Texas. Extensive demolition and salvaging of materials has occurred at LHAAP, but there are still many buildings or portions of buildings remaining. The entire installation was under the control of the U.S. Department of the Army (Army) until May 5, 2004, when approximately two thirds of the property was transferred to the U.S. Department of Interior's Fish and Wildlife Service (USFWS). The U.S. Army Environmental Center has the responsibility for the environmental restoration activities at LHAAP, with the management of the Army's property provided by the Base Realignment and Closure Office. The groundwater, surface water, sediment, and soil at LHAAP have been contaminated by past operations. Studies conducted at LHAAP identified contaminants such as volatile organic compounds (VOCs), heavy metals, perchlorate, and explosives in on-site media. Several areas of contamination are subject to investigation and cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (42 United States Code [USC] 9604). LHAAP sites were originally subdivided into five groups for environmental assessment. Environmental investigations were completed for Groups 1, 3, and 5 with a determination of no further action. Remedial investigation (RI)/FS activities are ongoing for Groups 2 and 4.

This FS presents an analysis of remedial alternatives for LHAAP-67 in accordance with CERCLA. LHAAP-67 was a 1.91-acre area that consisted of seven aboveground storage tanks. Site personnel indicate that the tanks were used for solvent storage. References to the other Group 4 sites (LHAAP-04, 08, 35A, 35B, 35C, 46, 47, 48, 50, and 60) are included within this FS, but the analysis of remedial alternatives within this FS is restricted to LHAAP-67.

This introduction presents the purpose and organization of the FS **(Section 1.1)**, background information for LHAAP **(Section 1.2)**, the FS scope and primary assumptions **(Section 1.3)**, and the human health risk assessment approach **(Section 1.4)**.

1.1 Purpose and Organization of Report

Environmental cleanup decision-making under CERCLA follows a prescribed sequence: remedial investigation (RI), FS, proposed plan and record of decision (ROD). The RI is the mechanism for collecting data to characterize site conditions, determine the nature and extent of the contamination, and assess risks to human health and the environment. The RI for the Group 4 sites has been completed and documented in two RI reports (Jacobs, 2002b; 2002c) and the baseline human health risk assessment report (Jacobs, 2003).

The FS takes the next step of identifying and evaluating remedial solutions to the environmental contamination identified at LHAAP-67. This step begins with the formulation of viable alternatives, which involves defining remedial action objectives (RAOs), general response actions (GRAs), volume or area of media to be addressed, and potentially applicable technologies and process options. After a reasonable number of appropriate alternatives have been formulated, the alternatives undergo a detailed analysis using nine established evaluation criteria. The detailed analysis profiles individual alternatives against the criteria and compares them with each other to gauge their relative performance. Each alternative that emerges, with the exception of the required "No Action" alternative, is expected to be protective of human health and compliant with applicable or relevant and appropriate requirements (ARARs) (unless a waiver is justified), both threshold requirements under CERCLA. The alternatives developed in this FS address the media and contaminants of concerns (COCs) at LHAAP-67 through a combination of land use controls and groundwater actions.

This FS is composed of the following sections:

- **Section 2**, "Site Description," summarizes the site background and setting, previous sampling investigations, and risk assessment conclusions; provides the conceptual site model for LHAAP-67, and discusses the LHAAP-67 media problem(s) that must be addressed.

- **Section 3**, "Remedial Action Objective and Remediation Levels," presents the RAO and a discussion of remediation levels. The chemical- and location-specific ARARs are presented in this section.

- **Section 4**, "Identification and Screening of Technologies and Process Options," summarizes the rationale for selecting technologies and process options for remediation of contamination to meet the RAO.

- **Section 5**, "Development and Description of Alternatives," presents the rationale for developing a range of alternatives, as well as a description of each alternative. Action-specific ARARs are presented.

- **Section 6**, "Detailed Analysis of Alternatives," evaluates, compares, and contrasts the benefits and costs of the alternatives.
- **Section 7**, "References," presents the references cited in this document.

Appendix A presents the cost basis for the remedial action alternatives.

The preferred alternative for LHAAP-67 will be presented in the proposed plan. The proposed plan will briefly summarize the alternatives studied in the FS, highlighting the key factors that lead to identifying the preferred alternative. The Army will submit the proposed plan to the regulatory agencies, Texas Commission on Environmental Quality (TCEQ) and U.S. Environmental Protection Agency (USEPA), and then to the public for review. After this review, the Army will release a ROD that documents the selected remedy, certifies that the remedy selection process was carried out in accordance with CERCLA, and addresses public comments on the proposed plan. Relevant documentation, including the RI, this FS, and subsequent documents are or will be available to the public in the Administrative Record for this project. The Administrative Record is housed at LHAAP and at the Marshall Public Library in Marshall, Texas.

1.2 Longhorn Army Ammunition Plant Background

1.2.1 Location

LHAAP is located in central-east Texas in the northeastern corner of Harrison County. The former Army installation occupies nearly 8,500 acres between State Highway 43 at Karnack, Texas, and the southwestern shore of Caddo Lake, as shown in **Figure 1-1**. The Army transferred approximately 5,032 acres to the USFWS on May 5, 2004 for management as the Caddo Lake National Wildlife Refuge and additional areas have been transferred since then. The remaining approximately 2,000 acres still under the Army's control include Groups 2 and 4 sites currently undergoing a Remedial Investigation/Feasibility Study (RI/FS). The Army intends to transfer the remaining property to the USFWS after the environmental response is completed.

The nearest cities are Marshall, Texas, approximately 14 miles to the southwest, and Shreveport, Louisiana, approximately 40 miles to the southeast. Caddo Lake, a large freshwater lake situated on the Texas-Louisiana border, bounds LHAAP to the north and east.

1.2.2 History

LHAAP was established in December 1941, near the beginning of World War II, when the Army issued a contract to build a six-line production facility for manufacturing TNT (Plant 1 area). The first flake of TNT was produced in October 1942. LHAAP ultimately produced 414 million pounds of TNT before production was halted in August 1945, near the end of the war, and the facility went on standby status.

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PLOT DATE: 3/01/04
FORMAT REVISION 5/13/02

IMAGE	X-REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
TYLER(250_000)	---	Houston, Texas	J. RDZ	1/28/04	J. MALINO	3/2/04	P. SRIVASTAV	3/9/04	845714-A20

REFERENCE:
U.S.G.S. QUADRANGLE OF
TYLER, TEXAS; LOUISIANA 1956, REVISED 1977
SCALE 1:250,000

Shaw®

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

FIGURE 1-1
LHAAP LOCATION MAP
LHAAP 32, GROUP 2, FEASIBILITY STUDY
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

In 1952, during the Korean War, the government undertook two new initiatives at LHAAP:

- A partially constructed facility on the site (Plant 2) was reactivated and refitted for pyrotechnics production. This facility produced 3.4 million pyrotechnic devices (e.g., photoflash bombs, simulators, hand signals, and 40-millimeter tracers) before production was discontinued in April 1956.
- A facility (Plant 3) was designed and built for producing solid-fuel rocket motors for tactical missiles. Actual rocket motor production began in December 1954. The last major propellant-loading activity in Plant 3 occurred in 1980. Over the intervening quarter century, LHAAP manufactured over 50 million pounds of composite propellant and delivered over 200,000 rocket motors.

Production of rocket motors continued to be the primary operation at LHAAP until 1965 when, due to the Vietnam conflict, Plant 2 was reactivated for the production of pyrotechnic and illuminating ammunition. In the years following Vietnam, LHAAP continued to produce flares and other basic pyrotechnic or illuminating items for the U.S. Department of Defense inventory. From September 1988 to May 1991, LHAAP was also used for the static firing and elimination of Pershing I and II rocket motors in compliance with the Intermediate-Range Nuclear Force Treaty in effect between the United States and the former Union of Soviet Socialist Republics.

Various media have been contaminated in certain areas by past industrial operations and waste management practices at LHAAP. Industrial operations involved the use of secondary explosives, rocket motor propellants, and various pyrotechnics, such as illuminating and signal flares and ammunition. Explosives included TNT and black powder. Typical composite propellants were composed of a rubber binder, an oxidizer such as ammonium perchlorate, and a powdered metal fuel such as aluminum. Pyrotechnics were generally composed of an inorganic oxidizer such as sodium nitrate, a metal powder such as magnesium, and a binder. Other materials used in the industrial operations included acids, lubricants, and solvents; particularly trichloroethene and methylene chloride. Waste management included sanitary wastewater treatment, industrial wastewater treatment, holding/evaporation ponds, storm water drainage, sanitary and industrial waste landfills, and demolition/burning grounds. Discharges and releases to surface water, groundwater, and other secondary media have occurred from the historical operations.

LHAAP was placed on the National Priorities List on August 9, 1990. A Federal Facility Agreement (FFA) among the USEPA, the Army, and the Texas Natural Resources Conservation Commission (TNRCC), now the TCEQ, became effective December 30, 1991. LHAAP became inactive in July 1997, and a year later the Army issued a contract to remove salvageable property. On May 5, 2004, the Army transferred control of approximately 5,032 acres of land to the USFWS **(Figure 1-2)**. The RI/FS process is continuing at the Groups 2 and 4 sites with the land still under the Army's control.

1.2.3 Physical Setting

LHAAP is located in an area of the country characterized by a mild climate with an average low temperature of 35 degrees Fahrenheit (ºF) and an average high of 91ºF. Precipitation averages 46.9 inches per year with a slight peak in the spring. LHAAP is characterized by mixed pine-hardwood forests that cover flat to gently rolling terrain. Most of the terrain at LHAAP has an average slope of 3 percent or less, but slopes as steep as 12 percent can be found in the western and northwestern portions of the installation and along Harrison Bayou.

LHAAP is a part of the Cypress Bayou Basin occurring in the Piney Woods ecological region of Texas. The gentle topography and mild climate support an abundant and diverse plant community with a diversity of habitats. This diversity suggests the potential for a large variety of animal species to inhabit LHAAP. As the buildings have been demolished, more and more of the facility has been left to nature with pine trees growing among concrete remnants. Common mammals found at LHAAP include white-tailed deer, red and gray foxes, rabbits, squirrels, opossums, skunks, armadillos, beavers, and raccoons. In addition to mammals, a total of 334 bird species have been documented as inhabiting Caddo Lake's drainage system and potentially inhabiting LHAAP sometime during the year. A reported 53 different reptile species inhabit the Cypress Bayou Basin. Up to 22 federal- and/or state-listed endangered or threatened species potentially inhabit LHAAP although only nine of the species have been confirmed.

Surface water at LHAAP drains to the northeast into Caddo Lake, part of Big Cypress Bayou, via four drainage systems **(Figure 1-2)**: Saunder's Branch, Harrison Bayou, Central Creek, and Goose Prairie Creek. Saunder's Branch of Martin's Creek flows onto LHAAP near the southeastern corner of the installation and flows northward into Caddo Lake. Approximately 11 percent of the heavily wooded eastern section of the plant is drained by this system. Harrison Bayou enters LHAAP on the southern edge of the installation. The bayou captures approximately 30 percent of the surface drainage of LHAAP and bisects the installation in a northeasterly direction. Central Creek enters LHAAP on its western edge just south of the town of Karnack. Approximately 30 percent of the surface drainage from the installation is transported to Caddo Lake via this drainage course. The headwaters of Goose Prairie Creek are located near the northwestern corner of the plant and consist of one larger creek and several smaller tributaries. Goose Prairie Creek flows across the northern edge of the installation and drains approximately 30 percent of LHAAP. The flows of Central Creek and Goose Prairie Creek are intermittent.

00039119

LHAAP- Group 4 Sites

LHAAP-04	PILOT WASTEWATER TREATMENT PLANT
LHAAP-08	SEWAGE TREATMENT PLANT
LHAAP-37	CHEMICAL LABORATORY
LHAAP-46	PLANT 2 AREA
LHAAP-47	PLANT 3 AREA
LHAAP-48	Y-AREA
LHAAP-50	FORMER SUMP WATER TANK
LHAAP-53	STATIC TEST AREA
LHAAP-58	SHOP AREA
LHAAP-60	PESTICIDE STORAGE BUILDINGS
LHAAP-67	ABOVEGROUND STORAGE TANK FARM

Legend:

- -·-·- APPROXIMATE SITE BOUNDARY
- ─ CREEK/BAYOU
- ⌖ LHAAP WATER SUPPLY WELLS
- ─ POTENTIOMETRIC SURFACE CONTOUR (DECEMBER 1998 DATA)

TOTAL ACREAGE AT LHAAP-67 TRANSFERED TO U.S. FISH AND WILDLIFE: 1.91 Ac.

S C AL E

0 2400 4800 FEET

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT
TULSA, OKLAHOMA

FIGURE 1–2
LHAAP MAP WITH GROUP 4 SITES
FEASIBILITY STUDY, LHAAP–67, GROUP 4

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

IMAGE	X–REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
---	---	Houston, Texas	J. RDZ	4/18/04	J. MALINO	4/19/04	P. SRIVASTAV	5/28/04	845714–B31T

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Plot Date/Time: 04/20/04 10:42am
Plotted by: colette.agabiti

The subsurface geology at LHAAP consists of a thin veneer of Quaternary alluvium overlying Tertiary age formations of the Wilcox and Midway Groups. Underlying these sediments are Cretaceous age formations of the Navarro and Taylor Groups.

The stratigraphic thickness of the uppermost Wilcox Group ranges from a maximum of 350 feet in the northwest corner of LHAAP to approximately 130 to 140 feet along the east side of the facility near Caddo Lake. The Wilcox Group constitutes the majority of the unconsolidated sediments underlying LHAAP. The Wilcox Group consists of interbedded sands, silts, and clays. These sediments were deposited in a regressive fluvial-deltaic and transgressive marine environment that resulted in considerable stratigraphic heterogeneity over short distances across the site.

The unconsolidated sediments of the Wilcox Group typically consist of three sandy, water-bearing zones separated by silty clay layers. The uppermost portion of the Wilcox Group at LHAAP consists of medium plastic sandy silts and clays ranging in thickness from approximately 5 to 15 feet. These surficial sediments are underlain by the first or shallow saturated sand zone, which ranges in thickness from 10 to 20 feet. This sand zone consists of silty fine sand containing some silt and clay lenses and is at first dry to moist and then generally becomes saturated at 15 to 20 feet below ground surface (bgs). A 5- to 20-foot-thick medium to highly plastic silt and clay layer underlies the shallow saturated sand zone. An intermediate saturated sand zone, consisting of fine to medium silty sand, is then encountered below the silty clay layer at 30 to 50 feet bgs. The intermediate saturated sand zone is generally less silty than the shallow saturated sand zone and exhibits higher hydraulic conductivity. A silt to silty clay layer is encountered beneath the intermediate saturated sand zone and ranges in thickness from 5 to 30 feet. Underlying this silt to silty clay layer, a massive homogeneous silty, clayey, fine sand layer is encountered at a depth that continues to the top of the underlying Midway Group (approximately 200 to 300 feet bgs).

Because of the high degree of stratigraphic heterogeneity, the level of interconnection between the shallow, intermediate, and deep water-bearing zones in the Wilcox Group deposits at LHAAP is highly variable. The depth to groundwater across the facility ranges from 1 to 70 feet bgs, with the typical depth at 12 to 16 feet. The regional groundwater flow direction is generally east-northeast towards Caddo Lake, but varies by site location.

Additional geologic and hydrogeologic information in included in the RI reports (Jacobs, 2002b, 2002c).

1.2.4 Current and Future Land Uses

LHAAP is located near the unincorporated community of Karnack, Texas. Karnack is a rural community with a population of 775 people. The incorporated community of Uncertain, Texas, population 205, is a resort area located to the northeast of LHAAP on the edge of Caddo Lake and an access point to Caddo Lake. The industries in the surrounding area consist of agriculture, timber, oil and natural gas production, and recreation.

LHAAP has been an industrial facility since 1942. Large production activities continued until the facility was determined to be in excess of the Army's needs. The plant area is now inactive and approximately three-fourths of the former plant area is now controlled by the USFWS. LHAAP is surrounded by a fence (except on the border with Caddo Lake), and current security measures at LHAAP preclude unlimited public access to areas within the fence. Approved access for hunters is very limited. It is expected that a trespasser also occasionally enters the fenced area.

The anticipated future use of the entire facility is as a wildlife refuge. There is no plan to develop LHAAP for industrial or residential use.

1.2.5 Current and Future Surface Water Uses

Streams on LHAAP currently support wildlife and aquatic life. While humans may have limited access to some streams during the annual hunts, there is no routine use of any streams on LHAAP by humans. The streams do not carry adequate numbers and size of fish to support either sport or subsistence fishing. The streams discharge into Caddo Lake. Caddo Lake is a large recreational area that covers 51 square miles and has a mean depth of 6 feet. The watershed of the lake encompasses approximately 2,700 square miles. It is used extensively for fishing and boating. Caddo Lake is a drinking water supply for multiple cities in Louisiana including Vivian, Oil City, Mooringsport, South Shore, Blanchard, Shreveport, and Bossier City.

The anticipated future uses of the streams and lake are the same as the current uses.

1.2.6 Current and Future Groundwater Uses

Groundwater in the deep zone under and near LHAAP is currently used as a drinking water source. There are currently five active water supply wells near LHAAP. One well is located in and owned by Caddo Lake State Park. The well is completed to a depth of 315 feet and has been in use since 1935. A second well owned by the Karnack Water Supply Corporation services the town of Karnack and is located approximately 2 miles southeast of town. This well is approximately 430 feet deep and has been in use since 1942. The Caddo Lake Water Supply Corporation has three wells located north and northwest of LHAAP. These three wells are identified as Caddo Lake Water Supply Corporation Wells 1, 2, and 3 and are all hydraulically upgradient to LHAAP. Water removal from these wells is not expected to affect groundwater flow at the site because of the remote locations of these wells from LHAAP and their depths of completion. In addition, there are several livestock and domestic wells located in the vicinity of LHAAP with depths averaging approximately 250 feet.

There are three water supply wells located on LHAAP **(Figure 1-2)**, and they supply water to the buildings currently in use on the installation. One well is located at the Fire Station/Security Office (northwest of LHAAP-67 and north of Goose Prairie Creek) and has been in use since 1997. A second is located approximately one-half mile southwest of the Fire Station/Security Office (directly south of LHAAP-58) and has been in use since 1999. The third is located immediately adjacent to the former administration building, currently used as offices for Caddo Lake Institute and the USFWS. Two additional wells previously supplied water to the installation, but these have been plugged and abandoned. None of the potable water supply wells are associated with or are in imminent danger from the localized contaminated groundwater at any of the Group 4 sites.

Based on the anticipated future use of the facility as a wildlife refuge, groundwater will not be used in the future as a drinking water source. However, to be conservative, it is assumed that another potential, though less likely future use, is industrial use. The future industrial scenario for LHAAP assumes limited use of groundwater as a drinking water source.

1.3 Feasibility Study Scope and Primary Assumptions

The scope of this FS is limited to LHAAP-67. LHAAP-67, known as the Aboveground Storage Tank Farm, was a 1.91-acre area that consisted of seven aboveground storage tanks. Site personnel indicate that the tanks were used for solvent storage. The tanks have since been removed and no structures remain at the site with the exception of a railroad bed.

The remedial alternatives presented in this FS address human health risk and ARAR exceedances. The installation-wide baseline ecological risk assessment (BERA) is currently underway and ecological risks pertinent to LHAAP-67 have not been identified. Remediation to address any ecological risks at LHAAP-67, if needed, is deferred to a future remedial decision. The existing Group 4 sites ecological risk assessment is a screening level ecological risk assessment in which available site data are compared against a single line of evidence (i.e., ecological benchmarks). A final decision on ecological protection is being deferred until the BERA is complete. Since ecological risk is not addressed by the alternatives (except indirectly through some surface water ARARs), this FS does not summarize the screening level ecological risk assessment.

Future decisions regarding ecological risk may result in the need to augment or replace certain components of the LHAAP-67 remedy that is eventually selected. While additional measures may be necessary to complete remediation activities for the LHAAP-67, implementation of the remedy derived from this FS will considerably improve environmental conditions and reduce the chance of contaminant release. Actions proposed in the alternatives and eventually selected for LHAAP-67 will not preclude additional remediation from any future decision for LHAAP.

This FS is based on the same data set used for the RI reports, which were used for the baseline human health risk assessment.

1.4 Human Health Risk Assessment Approach

The baseline human health risk assessment (Jacobs, 2003) estimated the risks that the Group 4 sites media pose to human receptors if no action is taken. The objective of the Group 4 sites human health risk assessment was to identify and estimate the potential human health risks associated with chemical contamination at the Group 4 sites, Goose Prairie Creek, Saunder's Branch, Central Creek, and Caddo Lake in the absence of any remediation. The results of the human health risk assessment for LHAAP-67 are summarized in **Section 2.3**. The risk information presented here and in **Section 2.3** is used to support alternative development, provide the basis for action, and identify the contaminant(s) and potential exposure pathways that must be addressed by remediation.

Four general steps are taken to accomplish a baseline risk assessment process:

- A *data evaluation* is conducted to organize the data and determine its usability for the risk assessment and to identify the chemicals of potential concern in each medium sampled.
- An *exposure assessment* is conducted to estimate the magnitude of potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are potentially exposed.
- A *toxicity assessment* considers the types of adverse health effects associated with chemical exposures and the relationship between magnitude of exposure and adverse effects.
- A *risk characterization* summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk.

1.4.1 Data Evaluation

Data collected during the RI Phases I, II, and III were evaluated to summarize analytical methods and associated data validation reports. Conventions used to interpret qualified data and duplicated results were described and it was determined that detection limits were below applicable TCEQ regulatory limits and, as such, the data are useable for the risk assessment. Conventions used in the identification of contaminants of potential concern (COPCs) in each medium were described and the chemicals were summarized in appropriate tables.

1.4.2 Exposure Assessment

Exposure pathway analysis during the risk assessment identified three human health exposure scenarios for quantification:

- Recreational: the current on-site trespasser exposed to surface soil and streams
- Industrial: the future on-site maintenance worker exposed to soil and groundwater
- Residential: the future off-LHAAP resident exposed to Caddo Lake

On-site exposure pathways evaluated for soil were ingestion, dermal absorption, and inhalation of dust and vapors. On-site exposure pathways evaluated for groundwater were ingestion, dermal contact while showering, and inhalation of vapors while showering. For this FS, the on-site receptor of concern is the future maintenance worker at LHAAP-67. The contribution of LHAAP-67 to any unacceptable off-site risks were included in the assessments of the on-site trespasser and of potential off-site residents exposed to Caddo Lake.

1.4.3 Toxicity Assessment

To characterize risk using the dose estimates calculated as part of the exposure assessment, toxicity values for cancer effects and noncancer (i.e., systemic toxicity) effects were gathered from approved sources. Primary among these sources were the USEPA Integrated Risk Information System and Health Effects Assessment Summary Tables. Additional toxicity values were obtained from the TCEQ and communications with the Superfund Technical Support Center in Cincinnati, Ohio.

The toxicity values used in the risk assessment were slope factors for cancer risks and reference doses (RfDs) and reference concentrations for systemic toxicity. Slope factors were used to quantitatively define the relationship between daily intake of a chemical and excess lifetime cancer risk (ELCR), and RfDs and concentrations were used to quantitatively define the relationship between daily intake of a chemical and systemic toxicity.

1.4.4 Risk Characterization

For carcinogens, risks are generally expressed as the incremental probability of an individual developing cancer over a lifetime because of exposure to the carcinogen. These risks are probabilities that usually are expressed in scientific notation (e.g., 1×10^{-6}). An ELCR of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1 million chance of developing cancer as a result of site-related exposure. This ECLR would be in addition to other cancer risks individuals face but who are not exposed to LHAAP media. The USEPA target ELCR range for site-related exposures is 1×10^{-4} to 1×10^{-6} (USEPA, 1989a).

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specific time period (usually to evaluate a chronic exposure) with an RfD derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called a hazard quotient (HQ). An HQ less than 1 indicates that a receptor's dose of a single contaminant is less than the RfD and that toxic non-carcinogenic effects from the chemical are unlikely. The hazard index (HI) is generated by adding the HQs for all COPCs that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may be reasonably exposed. An HI less than 1 indicates that, based on the sum of all HQs from different contaminants and exposure routes, toxic non-carcinogenic effects from all contaminants are unlikely. An HI greater than 1 indicates that site-related exposures might present a risk to human health (USEPA, 1989a).

The results of the risk assessment help to identify COCs. COCs are defined as contaminants detected at a site that significantly contribute to a pathway in an exposure scenario for a receptor that either (a) exceeds a cumulative ELCR of 1×10^{-4} or (b) exceeds a cumulative non-carcinogenic HI of 1. Contaminants are not considered to be significant contributors to risk if their individual carcinogenic risk contribution is less than 1×10^{-6} and their non-carcinogenic HQ is less than 1. The contributions of contaminants that contribute intermediate risks between 1×10^{-6} and 1×10^{-4} were included and discussed in the human health risk assessment for Group 4 sites (Jacobs, 2003) and their risks considered in this report.

2.0 Site Conditions and Previous Investigations

This section summarizes the historical setting, previous investigations, risk conclusions, the conceptual model, and the media problems for LHAAP-67. Information in this section is based on data obtained primarily from the following references:

- Group 4 Sites RI (Jacobs, 2002a)
- Group 4 Sites RI addendum (Jacobs, 2002b)
- Group 4 Sites FS (Jacobs, 2002c)
- Group 4 Sites Baseline Human Health Risk Assessment Report (Jacobs, 2003)

2.1 Background and Setting

LHAAP-67, known as the Aboveground Storage Tank Farm, is located in the central portion of LHAAP on the southeast corner of 48th Street and Ignatius Avenue **(Figure 2-1)**. The site covers an area of 1.91 acres. When operational, the site consisted of seven aboveground storage tanks. The exact size of each storage tank is not known. The tanks were surrounded with earthen dikes meant to contain potential spills. Site personnel indicate that the tanks were used for solvent storage. The tanks have been removed and the only structure remaining at the site is a railroad bed.

LHAAP-67 is relatively flat. Since removal of the tanks, a light vegetative cover has become established on the site. Surface drainage generally flows southeast, via overland flow or through man-made drainage swales and culverts, and eventually into Central Creek to the southeast. Runoff from the site enters Caddo Lake via Central Creek. Based on a 1998 potentiometric surface map and the location of Harrison Bayou, the shallow groundwater is assumed to flow east-southeast. Hydraulic conductivities in the installed wells vary from 1.2×10^{-5} to 1.0×10^{-2} centimeters (cm) per second.

Across the site, a silty clay is encountered in the subsurface (below surficial fill) and ranges in thickness from about 2 feet to 15 feet. The clay grades into a fine-grained sand, slightly silty in part and encountered approximately 13 feet to about 2 feet bgs, thickening toward the east-southeast. Initial depth to water, as noted from the drilling logs, is 13 to 16 feet bgs.

2.2 Summary of Sampling Investigations

Environmental media (soil and groundwater) at LHAAP-67 have been sampled and analyzed to identify potential contamination. Investigations at the Group 4 sites were conducted during Phase I through Phase III RIs and supplemental RIs (Jacobs, 2002a, 2002b). Sampling specific

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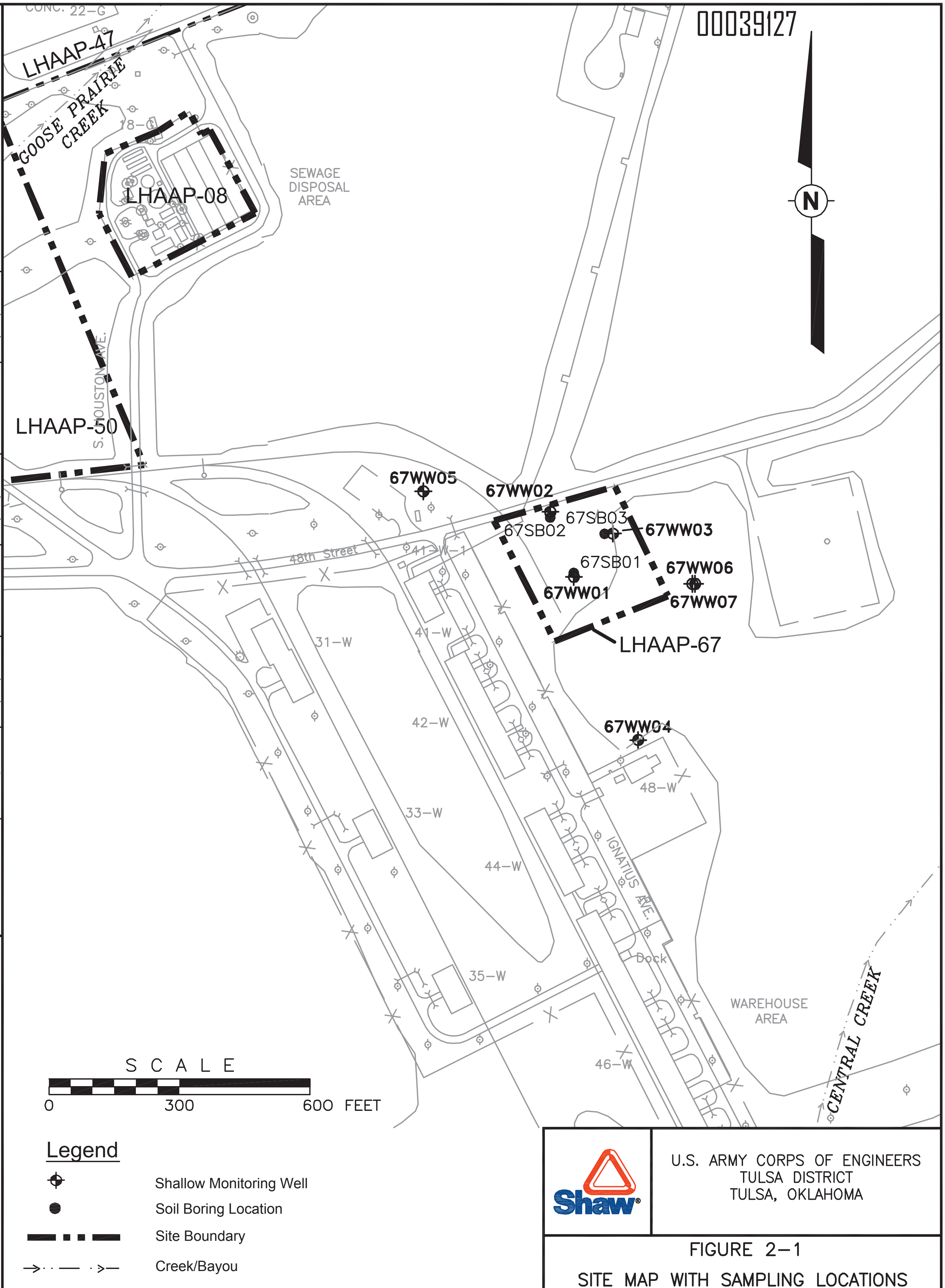

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FIGURE 2–1

SITE MAP WITH SAMPLING LOCATIONS
FEASIBILITY STUDY, LHAAP–67, GROUP 4

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

OFFICE	DRAWN BY	CHECKED BY	APPROVED BY	DRAWING NUMBER
Houston, Texas	*C. Agabiti* 4/18/04	*J. MALINO* 4/19/04	*P. Srivastav* 5/28/04	845714A26T

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Plotted by: colette.agabiti

to LHAAP-67 media was conducted during the Phase III RI (Jacobs, 2002b). The on-site sample locations are shown in **Figure 2-1**.

2.2.1 Phase III RI

In 1998, three groundwater wells were installed at LHAAP-67 and sampled for VOCs, semivolatile organic compounds (SVOCs), and metals. Soil borings were installed next to the existing monitoring wells and four additional groundwater wells were installed in 2000. The soil borings were sampled for VOCS, SVOCs, metals, and explosive compounds and the additional monitoring wells were sampled for VOCs, SVOCs, metals, explosive compounds, and perchlorate.

2.2.1.1 Soil Investigation

Three soil borings were installed as part of the Phase III investigation (Jacobs, 2002b). The soil borings were completed immediately adjacent to the existing wells since no soil samples were collected during the installation of the wells. Three soil samples were collected from each boring (0 to 0.5 feet bgs, 1 to 3 feet bgs, and 3 to 5 feet bgs). The samples were analyzed for VOCs, SVOCs, metals, and explosive compounds.

No SVOCs or explosive compounds were detected in any of the soil samples. One VOC, methylene chloride, was detected in the soil samples at a maximum concentration of 5.9 micrograms per kilogram (µg/kg). Barium, detected in two samples with concentrations ranging from 45.1J milligrams per kilogram (mg/kg) to 837J mg/kg, and lead, detected in four samples with concentrations ranging from 10.6 mg/kg to 55.8 mg/kg, were the only metals detected at concentrations exceeding background levels.

2.2.1.2 Groundwater Investigation

Three groundwater monitoring wells (67WW01, 67WW02, and 67WW03) were installed and sampled in 1998 (Jacobs, 2002b). These wells had 10-foot screens positioned in the upper saturated zone (top of screen ranging from 11 to 16 feet bgs) to evaluate the shallow groundwater. The wells were sampled for VOCs, SVOCs, metals, and anions.

No SVOCs were detected in the groundwater samples. Five VOCs (1,1,1-trichloroethane [TCA], 1,1,2-TCA, 1,2-dichloroethane [DCA], trichloroethene [TCE], and 1,1-dichloroethene [DCE]) were detected at concentrations exceeding their respective maximum contaminant levels (MCLs). Multiple metals and anions were detected in the three monitoring wells. Only thallium, having a maximum concentration of 0.0021 milligrams per liter (mg/L), exceeded its MCL of 0.002 mg/L. Maximum concentrations of contaminants detected at LHAAP-67 are provided in **Table 2-1**.

Table 2-1
Summary of Detected Constituents in Groundwater

Analytes Detected	Maximum Concentration
	LHAAP-67
Volatile Organic Compounds (μg/L)	
1,1,1-Trichloroethane (COC)	1,800
1,1,2-Trichloroethane (COC)	33
1,1-Dichloroethane	14
1,1-Dichloroethene (COC)	380
1,2-Dichloroethane (COC)	27
Chloroform	2.83
Methyl ethyl ketone (2-Butanone)	61
Methylene chloride	1.37
Toluene	91
Trichloroethene (COC)	6.3
Metals (mg/L)	
Aluminum	6
Barium	3.3
Beryllium	0.0008
Cadmium	0.0026
Calcium	373
Chromium (total)	0.09
Cobalt	0.12
Copper	0.027 J
Iron	9.6
Lead	0.007
Magnesium	190
Manganese	3.4
Nickel	0.18 J
Potassium	7.5
Selenium	0.014
Sodium	870
Strontium	7.8
Thallium	0.0021
Zinc	0.054 J
Anions (mg/L)	
Sulfate (as SO_4)	260

Notes and Abbreviations:

1.	*These data are from the Remedial Investigation Report Addendum for the Group 4 Sites (Sites 04, 08, 67) (Jacobs, 2002b)*
J	*The analyte was not positively identified: the associated numerical value is the approximate concentration of the analyte in the sample*
COC	*contaminant of concern*
μg/L	*micrograms per liter*
mg/L	*milligrams per liter*

An additional round of groundwater samples was collected in September 2004. The results were reported in the Draft Final Data Gaps Investigation Report (Shaw, 2005a). The results were lower than those reported in earlier investigations.

In 2000, Jacobs installed four additional groundwater wells (67WW04 through 67WW07) to further delineate the extent of VOC contamination. Monitoring well 67WW05 was installed upgradient from the site and wells 67WW04 and 67WW07 were installed downgradient of the site. Three wells (67WW04, 67WW05, and 67WW07) were screened to monitor the shallow groundwater (11 feet to 16 feet bgs). Well 67WW06 was installed adjacent to 67WW07 and was screened to a depth of 38 feet bgs to evaluate the downward migration of VOCs. The wells were sampled for VOCs, SVOCs, metals, explosives, and perchlorate (Jacobs, 2002b).

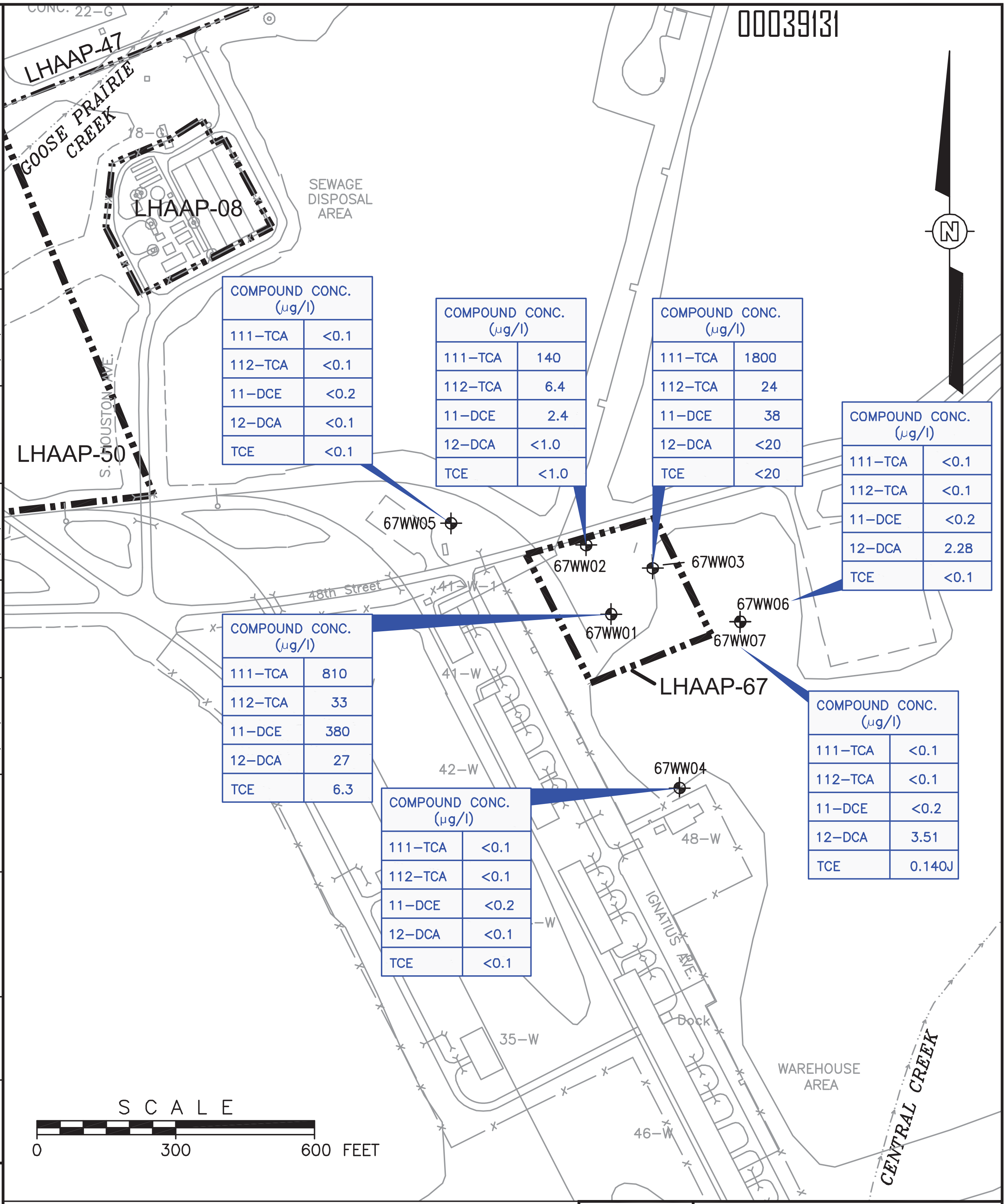
No SVOCs, explosives, or perchlorate were detected in the four groundwater wells. 1,2-DCA was detected in wells 67WW06 and 67WW07 at concentrations below its MCL (Jacobs, 2002c). Chloroform, methylene chloride, and TCE were also detected in well 67WW06 at concentrations below their respective MCLs. Multiple metals and anions were detected in the four groundwater wells, but only barium (maximum concentration of 3.3 mg/L) was detected above its MCL of 2 mg/L. **Table 2-1** provides maximum concentrations of contaminants. A potentiometric map based on 1998 water level data indicates that the groundwater flow is to the southeast, as shown in **Figure 2-2**.

2.3 Risk Assessment Summary

This summary is based on the conclusions presented in the Final Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites (Jacobs, 2003). During the risk assessment, soil and groundwater data were used to calculate the aggregate risk results, which were then compared to the USEPA target risk range of 1×10^{-4} to 1×10^{-6} for the ELCR and an HI of 1. If there is no unacceptable risk associated with a medium and the medium is not contributing to a risk or ARAR exceedance of another medium, then the medium is not identified in this FS for remediation.

Groundwater data with unacceptable risk were also compared with MCLs, which are proposed as ARARs for some of the alternatives in this FS. If a groundwater contaminant does not exceed its MCL and does not pose an unacceptable risk, it is not identified for remediation in this FS.

Only the human health risks and hazards to a future maintenance worker under an industrial scenario are presented in this FS for soil and groundwater. The environmental risk will be determined based on the results of the BERA (to be completed).



67WW05

COMPOUND	CONC. (μg/l)
111-TCA	<0.1
112-TCA	<0.1
11-DCE	<0.2
12-DCA	<0.1
TCE	<0.1

67WW02

COMPOUND	CONC. (μg/l)
111-TCA	140
112-TCA	6.4
11-DCE	2.4
12-DCA	<1.0
TCE	<1.0

67WW03

COMPOUND	CONC. (μg/l)
111-TCA	1800
112-TCA	24
11-DCE	38
12-DCA	<20
TCE	<20

67WW06

COMPOUND	CONC. (μg/l)
111-TCA	<0.1
112-TCA	<0.1
11-DCE	<0.2
12-DCA	2.28
TCE	<0.1

67WW01

COMPOUND	CONC. (μg/l)
111-TCA	810
112-TCA	33
11-DCE	380
12-DCA	27
TCE	6.3

67WW07

COMPOUND	CONC. (μg/l)
111-TCA	<0.1
112-TCA	<0.1
11-DCE	<0.2
12-DCA	3.51
TCE	0.140J

67WW04

COMPOUND	CONC. (μg/l)
111-TCA	<0.1
112-TCA	<0.1
11-DCE	<0.2
12-DCA	<0.1
TCE	<0.1

Legend

⊕ SHALLOW MONITORING WELL
▬ ▪ ▬ SITE BOUNDARY
→ CREEK/BAYOU
12-DCA: 1,2-DICHLOROETHANE
11-DCE: 1,1-DICHLOROETHENE
111-TCA: 1,1,1-TRICHLOROETHANE
112-TCA: 1,1,2-TRICHLOROETHANE
TCE: TRICHLOROETHENE

NOTE: ANALYTICAL DATA FROM 1998 AND 2000 SAMPLING EVENT BY JACOBS ENGINEERING

Shaw

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TULSA, OKLAHOMA

FIGURE 2-2
SHALLOW GROUNDWATER CONTAMINATION MAP
FEASIBILITY STUDY, LHAAP-67, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

DRAWING NUMBER	845714-A23
APPROVED BY	P. SRIVASTAV 8/18/05
CHECKED BY	G. JONES 8/18/05
DRAWN BY	J. RDZ 7/27/04
OFFICE	Houston, Texas
X-REF	---
IMAGE	---

PLOT DATE: 8/05/04
FORMAT REVISION 3/25/99

2.3.1 Soil

Soil in the risk assessment is defined as surface soil (0 to 2 feet in depth). Future maintenance worker exposure to on-site soil at LHAAP-67 generated an HI of 0.03, below the benchmark of 1. The carcinogenic risk calculated is 2.9 x 10^{-7}. This risk falls below the acceptable range (1 x 10^{-6} to 1 x 10^{-4}).

2.3.2 Groundwater

The baseline human health risk assessment reported unacceptable carcinogenic risk (greater than 1 x 10^{-4}) and non-carcinogenic hazard for LHAAP-67 groundwater for the future maintenance worker under an industrial scenario (ELCR of 3.1×10^{-3} and HI of 4.1). 1,1-DCE accounted for approximately 98 percent of the total groundwater carcinogenic risk.

2.4 Media Contamination Assessment

Data presented in the remedial investigation and the human health risk assessment indicate that chlorinated compounds in soil pose no unacceptable risk to human health while chlorinated compounds in groundwater at LHAAP-67 pose an unacceptable risk to human health as discussed in more detail in this section.

2.4.1 Soil Contamination

One VOC, methylene chloride, and multiple metals were detected in LHAAP-67 soil during the remedial investigation **(Section 2.2.1.1)**. Despite the detection of the metals and methylene chloride, none of the contaminants were determined to have unacceptable carcinogenic risk or non-carcinogenic hazard to a future maintenance worker at LHAAP under an industrial scenario.

2.4.2 Groundwater Contamination

An assessment of groundwater contamination at LHAAP-67 was presented in **Section 2.2.1.2**. Based on the human health risk assessment, groundwater at LHAAP-67 poses an unacceptable carcinogenic risk and non-carcinogenic hazard to a future maintenance worker at LHAAP under an industrial scenario. The COCs listed in **Table 2-1** for the LHAAP-67 groundwater are 1,1,1-TCA, 1,1,2-TCA, 1,1-DCE, 1,2-DCA, and TCE due to exceedance of their respective MCLs. The detected COC concentrations in groundwater are shown on **Figure 2-2**.

2.5 Conceptual Site Model

The overall conceptual model for LHAAP-67 is illustrated in **Figure 2-3**. The model presents those pathways that have been demonstrated to be complete as evidenced by the presence of contamination and are being considered for remediation. Those pathways that are likely incomplete or have negligible impact are not being considered for remediation. In the past, releases from the tanks likely contaminated the soil and then leached from the soil into the groundwater. Previous soil investigation indicated the presence of methylene chloride at a relatively low concentration of 5.9 µg/kg in the 0-5 foot depth interval. Based on the soil

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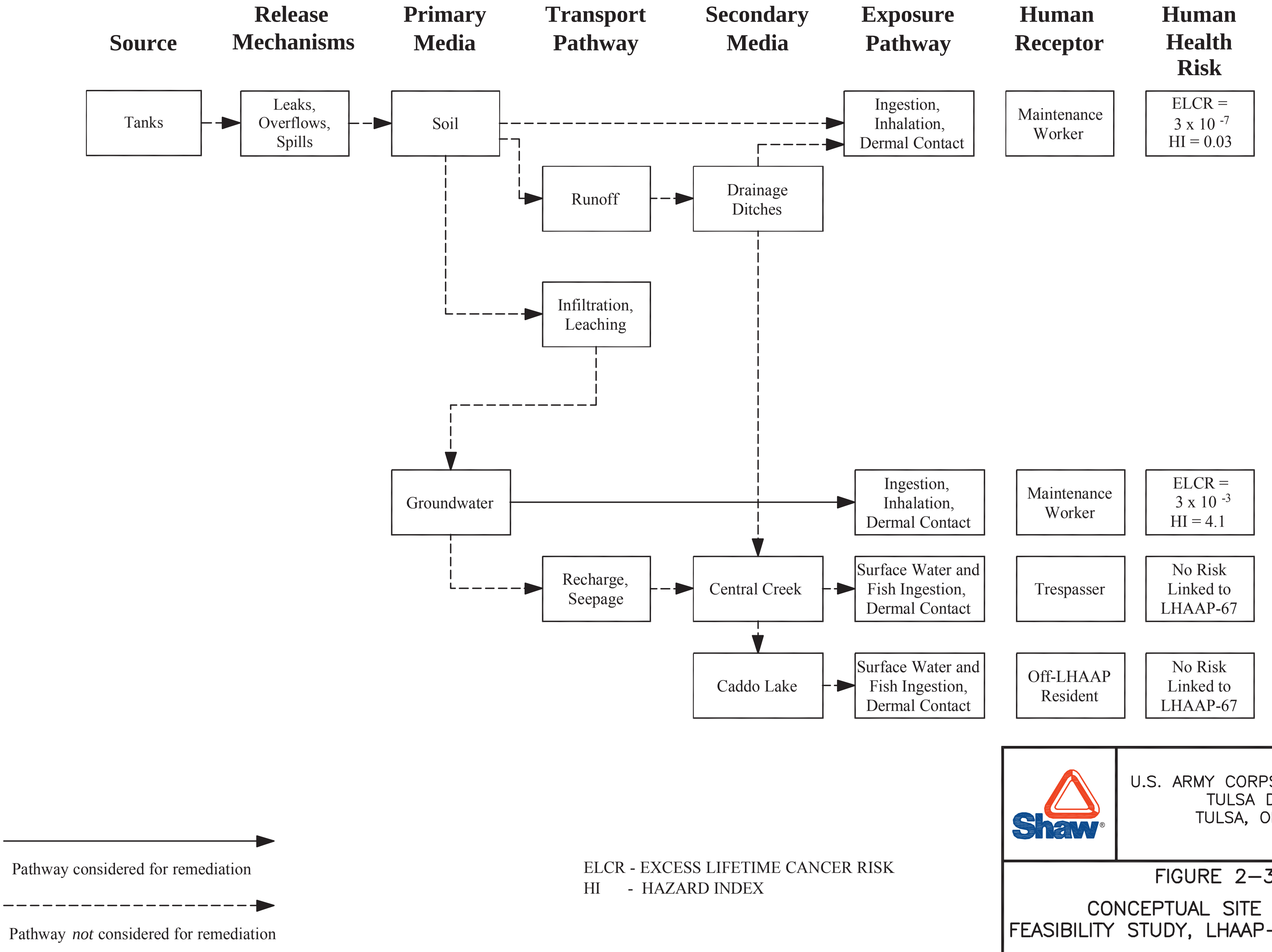

ELCR - EXCESS LIFETIME CANCER RISK
HI - HAZARD INDEX

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TULSA, OKLAHOMA

FIGURE 2–3

CONCEPTUAL SITE MODEL
FEASIBILITY STUDY, LHAAP–67, GROUP 4

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

sampling investigation, residual contamination is likely not present in the soils at significant levels. This is likely due to the volatilization and vertically downward migration of the contaminants that might have been present in the vadose zone. A relatively small area of contamination is observed in the groundwater **(Figure 2-2)**, with the extent of contamination defined, both laterally and vertically. The groundwater contamination poses an unacceptable carcinogenic risk and non-carcinogenic hazard to a future maintenance worker under an industrial scenario.

Additionally, the COCs present in groundwater beneath LHAAP-67 could also potentially discharge to surface water in Central Creek located to the southeast of the site, which flows to Caddo Lake, a drinking water source. The shallow groundwater potentiometric surface indicates that the groundwater from LHAAP-67 has an easterly and southeasterly flow and may likely discharge into Central Creek. However, surveyed elevation data are not available for Central Creek in the area near LHAAP-67. Elevation data from USGS topographic maps indicate that the shallow potentiometric surface may be several feet below the bottom of Central Creek and thus the shallow groundwater may not discharge into Central Creek. Due to the uncertainty in the exact elevation of Central Creek near LHAAP-67, it is assumed, for the purpose of this FS, that the groundwater may discharge into Central Creek during certain seasons of the year when the water table is high. A survey to collect elevation data from Central Creek near LHAAP-67 is scheduled to be conducted in conjunction with other investigative activities at LHAAP.

Modeling calculations were completed to assess the potential for groundwater COCs at LHAAP-67 to migrate toward and discharge to nearby Central Creek (Shaw, 2005b). Two different scenarios were modeled using a total simulation period of 100 years, which was long enough to capture the maximum contaminant concentrations where groundwater discharges into Central Creek. The first scenario assumes an instantaneous source in which there is no contaminant leaching from vadose zone soil to groundwater. The second scenario, which is more conservative and less likely, assumes a continuous source of contaminant leaching from the vadose zone soil to groundwater over time. This scenario was considered in order to account for a case where a VOC source may be present in the soil in an area or depth that was not sampled during the RI. Based on the results of the instantaneous source model, the maximum COC concentrations were below their respective MCLs where groundwater discharges into Central Creek. Furthermore, based on the results of the continuous source model, multiple groundwater COCs could eventually exceed their respective MCLs where groundwater discharges into Central Creek in less than 16, but up to 29 years. Therefore, additional modeling was completed with calculated dilution within Central Creek. The resultant concentrations of the COCs in Central Creek after dilution were less than 3 percent of their respective MCLs. It is, therefore, concluded that contaminants present in the groundwater at LHAAP-67 will not adversely impact the surface water.

3.0 Remedial Action Objective and Remediation Levels

This section identifies the RAO **(Section 3.1)**, potential chemical- and location-specific ARARs **(Section 3.2)**, and preliminary remediation levels **(Section 3.3)** for LHAAP-67. The RAO identifies the general goals or end points that the remediation will accomplish, while the preliminary remediation levels identify specific cleanup standards for each medium of concern based on risk or ARARs. The remediation levels may be applied to individual contaminants.

3.1 Remedial Action Objective

The purpose of the RAO is to protect human health and meet ARARs. Because results of the ecological risk assessment will be addressed in a future decision, the RAO does not specifically address ecological risk, except as it forms the basis of certain ARARs. Implementation of the remedy derived from this FS is expected to considerably reduce the potential human health risk posed by the groundwater contaminants at LHAAP-67.

The reasonably anticipated, future uses of LHAAP streams, land, and groundwater are an important consideration in determining the appropriate extent of remediation for LHAAP-67.

- Streams on LHAAP are used for supporting wildlife and aquatic life. Although there is no routine use of the streams by humans, future use as a wildlife refuge will be the basis for setting stream protection goals.
- LHAAP land use for the last 50 years has been industrial. The surrounding community is rural to lightly populated. There is little to no demand for residential growth. The anticipated future use of the installation is as a wildlife refuge. However, because of its historical use and to provide conservative protection, future industrial land use (250 days per year [with an assumed 8-hour work day] for 25 years for a future maintenance worker) will be the basis for setting goals and remediation levels for land areas.
- Groundwater remediation goals will be based on a future industrial scenario, which includes limited ingestion of groundwater.

The RAO for LHAAP-67, which takes into account the future uses discussed above, is to prevent exposure to contaminated groundwater in excess of the 1×10^{-4} to 1×10^{-6} target risk range and an HI of 1 for the future maintenance worker, and to prevent potential site groundwater impacts to nearby surface water bodies to the extent that ARARs are met.

3.2 Chemical- and Location-Specific ARARs

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) 300.430(f)(1)(ii)(B) states that on-site remedial actions conducted under CERCLA must attain, or have waived, legally applicable ARARs under federal or more stringent state environmental or facility siting laws identified at the time of the ROD signature.

This section provides a preliminary identification and evaluation of potential federal and State of Texas chemical- and location-specific ARARs for the remediation of LHAAP-67 under CERCLA.

3.2.1 Definitions and Methods

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site (40 CFR 300.5). A requirement is applicable if all the jurisdictional and site-specific prerequisites of the requirement are met; that is, a requirement is applicable if it directly and fully addresses the situation at the site.

Relevant and appropriate requirements are those substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site (40 CFR 300.5). The criteria for determining relevance and appropriateness are listed at 40 CFR 300.400(g)(2). A relevant and appropriate requirement must be complied with to the same extent as an applicable requirement.

To qualify as a state ARAR mandating cleanup standards under 40 CFR 300.400(g)(4) of the NCP, a state requirement must be (1) promulgated (of general applicability and legally enforceable), (2) an environmental or facility siting law or regulation, (3) substantive (not procedural or administrative), (4) more stringent than a comparable federal requirement, (5) identified by the state in a timely manner, and (6) consistently applied throughout the state. Pursuant to USEPA guidance (1989a), where USEPA has delegated to a state the authority to implement a federal program, the state regulations replace the equivalent federal requirements as the potential ARARs.

ARARs are generally divided into chemical-, location-, and action-specific requirements. Chemical-specific ARARs are usually promulgated health- or risk-based numerical values or methods used to determine acceptable concentrations of chemicals that may be found in, or discharged to, the environment. Location-specific ARARs restrict actions or contaminant concentrations in certain environmentally sensitive areas. Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes.

An on-site action need not comply with administrative parts of requirements identified as ARARs. According to USEPA guidance (1988a), administrative requirements are mechanisms that facilitate the implementation of the related substantive requirements of a statute or regulation (e.g., approval of or consultation with administrative bodies, documentation, permit issuance, reporting, record keeping, and enforcement).

The NCP at 40 CFR 300.400(e)(1) exempts on-site actions from having to obtain federal, state, or local permits and defines “on-site” as meaning “the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for the implementation of the response action.” However, on-site actions must still be in compliance with any substantive permit requirements. Off-site actions must not only comply with requirements that are legally applicable, but they must comply with both the substantive and the administrative parts of those requirements. Permits, if required, must be obtained for all remedial activities conducted off site (40 CFR 300.400[e][2]). Statutory waivers of ARARs (40 CFR 300.430[f][1][ii][C]) may not be used for off-site actions.

The USEPA has noted in its CERCLA guidance that if attainment of a numerical value that is a potential chemical-specific ARAR is impossible because the background level of the chemical subject to CERCLA authority is higher than that of the potential ARAR, the numeric criterion would not be considered an ARAR (USEPA, 1991).

ARARs include only federal or more stringent state environmental laws and regulations and do not include occupational safety regulations. The USEPA requires compliance with the Occupational Safety and Health Administration (OSHA) standards and other worker protection requirements under Section 300.150 of the NCP, not through the ARARs process. Therefore, none of the promulgated OSHA regulations (e.g., 29 CFR 1926, 29 CFR 1910) are addressed here as ARARs.

In addition to ARARs, 40 CFR 300.400(g)(3) states that federal or state nonpromulgated advisories or guidance may be identified as to-be-considered (TBC) guidance for contaminants, conditions, and/or actions at the site. TBCs include non-promulgated criteria, advisories, guidance, and proposed standards. TBCs are not ARARs because they are neither promulgated nor enforceable. TBCs may be used to interpret ARARs and to determine preliminary remediation goals when ARARs do not exist for particular contaminants or are not sufficiently protective to develop cleanup goals. TBCs, such as guidance or policy documents, developed to implement regulations may be considered and used where necessary to ensure protectiveness.

Potential TBCs evaluated as part of this investigation are listed in **Tables 3-1, 3-2, and 3-3** and are discussed herein.

Chemical-specific requirements are discussed in **Section 3.2.2**; **Table 3-1** includes a narrative listing of chemical-specific ARARs/TBCs for LHAAP-67. **Table 3-2** includes a numerical listing of chemical-specific ARARs/TBCs for surface water at LHAAP-67, and **Table 3-3** includes a numerical listing of chemical-specific ARARs/TBCs for groundwater. Location-specific requirements for the sensitive resources potentially identified at LHAAP-67 are discussed in **Section 3.2.3** and listed in **Table 3-4**. Action-specific ARARs evaluated as part of the screening and detailed analysis of alternatives in this FS are discussed in **Section 5.3**.

3.2.2 Chemical-Specific ARARs

3.2.2.1 Chemical-Specific ARARs for Surface Water

Based on December 1998 groundwater level measurements, contaminants in groundwater at LHAAP-67 may likely migrate toward Central Creek. Protection of surface water through source control actions for groundwater must ensure that chemical-specific ARARs for surface water are met. These ARARs are listed in **Table 3-2** and include the legally applicable Texas surface water quality standards (30 Texas Administrative Code [TAC] 307) and, for those contaminants that have no set Texas surface water quality standard, the relevant and appropriate federal ambient water quality criteria (AWQC).

3.2.2.1.1 State Surface Water Quality Standards

General and Numeric Criteria. Texas has promulgated surface water quality standards in 30 TAC 307 that must be met in waters of the State, depending on the site-specific classifications for the particular waters or segments of waters (as listed in 30 TAC 307.10, Appendices A–E). The standards include 30 TAC 307.4 (*General Criteria*), 30 TAC 307.5 (*Antidegradation*), 30 TAC 307.6 (*Toxic Materials*), and 30 TAC 307.7 (*Site-Specific Uses and Criteria*). Sections 307.8 (*Application of the Standards*) and 307.9 (*Determination of Standards Attainment*) address how compliance with the standards is implemented and measured.

Table 3-1
Potential Chemical-Specific ARARs/TBCs

Citation	Activity or Prerequisite/Status	Requirement
Groundwater		
State of Texas Primary Drinking Water Standards 30 TAC 290, Subchapter F	Applicable to drinking water at the tap**—relevant and appropriate** for remediation of Class I (potable) groundwater	Must not exceed drinking water standard for water designated as a current or potential source of drinking water. See Table 3-3 for specific numeric criteria.
Federal Safe Drinking Water Act MCLs/Non-Zero MCLGs 40 CFR 141	Applicable to drinking water at the tap**—relevant and appropriate** for remediation of Class I (potable) groundwater if no state MCL is available for a particular contaminant	Must not exceed MCLs/non-zero MCLGs for water designated as a current or potential source of drinking water. See Table 3-3 for specific numeric criteria.
Proposed Federal Safe Drinking Water Act MCLs/Non-Zero MCLGs USEPA, "Primary Drinking Water Standards – Proposed Rule," 59 FR 65578, December 20, 1994	Applicable to drinking water at the tap**—TBC** for remediation of Class I (potable) groundwater if no state or federal MCL/non-zero MCLG is available for a particular contaminant	Must not exceed proposed MCLs/non-zero MCLGs for water designated as a current or potential source of drinking water. See Table 3-3 for specific numeric criteria.
Surface Water		
State of Texas Surface Water Quality Standards: General Criteria and Toxic Materials Criteria 30 TAC 307.4; 30 TAC 307.6	Applicable to surface waters of the state**—applicable** if water is discharged to a surface water body or surface waters are remediated as part of the remedial action	Discharges to waters of the state must not cause in-stream exceedance of numeric and narrative water quality standards. Remediation of contaminated surface waters must ensure that numeric and narrative water quality standards are achieved, as determined by Section 307.8 (Application of the Standards) and Section 307.9 (Determination of Standards Attainment). See Table 3-2 for specific numeric criteria.
State of Texas Surface Water Quality Standards: Antidegradation 30 TAC 307.5	Applicable to surface waters of the state**—applicable** if water is discharged directly to a surface water body or surface waters are remediated as part of the remedial action	No activities subject to regulatory action that could cause degradation of waters exceeding fishable/swimmable quality will be allowed. Degradation is defined as a lowering of water quality by more than a de minimis extent, but not to the extent that an existing use is impaired. Water quality sufficient to protect existing uses will be maintained. The highest water quality sustained since November 28, 1975, defines baseline conditions for determinations of degradation.

Table 3-1 *(Continued)*
Potential Chemical-Specific ARARs/TBCs

Citation	Activity or Prerequisite/Status	Requirement
Federal Ambient Water Quality Criteria 40 CFR 131.36(b)(1)	Toxics criteria for those states not complying with CWA Section 303(c)(2)(B)—**relevant and appropriate** for remediation of surface water if no state WQC is available for a particular contaminant	Toxics must not exceed numeric criteria, based on use classifications, in surface water. See Table 3-2 for specific numeric criteria.

Abbreviations:

ARAR	*applicable or relevant and appropriate requirement*
CFR	*Code of Federal Regulations*
CWA	*Clean Water Act of 1972*
USEPA	*U.S. Environmental Protection Agency*
FR	*Federal Register*
FS	*feasibility study*
LHAAP	*Longhorn Army Ammunition Plant*
MCL	*maximum contaminant level*
MCLG	*maximum contaminant level goal*
TAC	*Texas Administrative Code*
TBC	*to-be-considered [guidance]*
WQC	*water quality criterion*

Table 3-2
Potential Federal and State Chemical-Specific ARARs for Surface Water Contamination (μg/L or ppb)

Analyte ["(c)" indicates a carcinogen]	Protection of Human Health		Protection of Aquatic Life	
	Texas WQC Freshwater Consumption of Water and Fish[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Consumption of Fish Only[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Acute Criteria[b,c] [30 TAC 307.6(c)(1)]	Texas WQC Freshwater Chronic Criteria[c,d] [30 TAC 307.6(c)(1)]
Acrolein		780^{e}		
Acrylonitrile (c)	1.28	10.9		
Aldrin (c)	0.00408	0.00426	3.0	
Aluminum			$991w^{f,g}$	
Anthracene		$110,000^{e}$		
Antimony		$4,300^{e}$		
Arsenic (c) (inorganic)	50	1.4^{e}	$360w^{f,g}$	$190w^{f,g}$
Barium	2,000			
Benzene (c)	5	106		
Benzidene (c)	0.00106	0.00347		
Benzo(a)anthracene (c)	0.099	0.810		
Benzo(a)pyrene (c)	0.099	0.810		
Benzo(b)fluoroanthene (c)		0.31^{e}		
Benzo(k)fluoranthene (c)		0.31^{e}		
alpha-BHC (c)	0.163	0.413		
beta-BHC (c)	0.570	1.45		
gamma-BHC [Lindane] (c)	0.2	2.00	2.0	0.08
bis(2-Chloroethyl)ether (c)		14.0^{e}		
bis(Chloromethyl)ether	0.00462	0.0193		
bis(2-Chloroisopropyl)ether		$170,000^{e}$		
bis(2-Ethylhexyl) phthalate (c)		59.0^{e}		
Bromodichloromethane (c)		220^{e}		
Bromoform (c)		$3,600^{e}$		
Cadmium	5		$26.4^{f,h}$	$1.03^{f,h}$
Carbaryl			2.0	
Carbon tetrachloride (c)	3.76	8.4		
Chlordane (c)	0.0210	0.0213^{i}	2.4	0.004
Chlorobenzene	776	1,380		
Chlorodibromomethane (c)	9.20	71.6		
Chloroform (c)	100	1,292		
Chlorpyrifos			0.083	0.041
Chromium (hexavalent)	100	$3,320^{f}$	15.7^{f}	10.6^{f}
Chromium (trivalent)			$549^{f,h}$	$178^{f,h}$

Table 3-2 *(continued)*
Potential Federal and State Chemical-Specific ARARs for Surface Water Contamination (μg/L or ppb)

Analyte ["(c)" indicates a carcinogen]	Protection of Human Health		Protection of Aquatic Life	
	Texas WQC Freshwater Consumption of Water and Fish[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Consumption of Fish Only[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Acute Criteria[b,c] [30 TAC 307.6(c)(1)]	Texas WQC Freshwater Chronic Criteria[c,d] [30 TAC 307.6(c)(1)]
Chrysene (c)	0.417	8.1		
Copper			18.4[f,h]	12.3[f,h]
Cresols	3,313	13,116		
Cyanide (free)	200	220,000[e]	45.8	10.7
Danitol	0.709	0.721		
2,4-D	70			
4,4-DDD (c)	0.0103	0.010		
4,4-DDE (c)	0.00730	0.007		
4,4-DDT (c)	0.00730	0.007	1.1[e]	0.001[e]
Demeton				0.1
Dibenzo(a,h)anthracene (c)		0.31[e]		
1,2-Dibromoethane	0.014	0.335		
1,2-Dichlorobenzene		17,000[e]		
1,3-Dichlorobenzene		2,600[e]		
1,4-Dichlorobenzene	75	2,600[e]		
3,3-Dichlorobenzidine (c)		0.77[e]		
Dichlorobromomethane—see Bromodichloromethane				
1,2-Dichloroethane (c)	5	73.9		
1,1-Dichloroethylene (c)	1.63	5.84		
2,4-Dichlorophenol		790[e]		
1,3-Dichloropropene	22.8	161		
Dicofol	0.215	0.217	59.3	19.8
Dieldrin (c)	0.00171	0.002	2.5	0.002
Diethylphthalate		120,000[e]		
Dimethylphthalate		2,900,000[e]		
Di-*n*-butyl phthalate		12,000[e]		
2,4-Dinitrophenol		14,000[e]		
2,4-Dinitrotoluene (c)		91[e]		
2,3,7,8-TCDD (Dioxin)	1.34×10^{-7} [j]	1.40×10^{-7} [j]		
Diuron			210	70
alpha-Endosulfan		2.0[e]	0.22	0.056
beta-Endosulfan		2.0[e]	0.22	0.056
Endosulfan sulfate		2.0[e]	0.22	0.056
Endrin	1.27	1.34	0.18	0.002

Table 3-2 *(continued)*
Potential Federal and State Chemical-Specific ARARs for Surface Water Contamination (μg/L or ppb)

Analyte ["(c)" indicates a carcinogen]	Protection of Human Health		Protection of Aquatic Life	
	Texas WQC Freshwater Consumption of Water and Fish[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Consumption of Fish Only[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Acute Criteria[b,c] [30 TAC 307.6(c)(1)]	Texas WQC Freshwater Chronic Criteria[c,d] [30 TAC 307.6(c)(1)]
Endrin aldehyde		0.81[e]		
Ethylbenzene		29,000[e]		
bis(2-Ethylhexyl) phthalate (c)		59[e]		
Fluoranthene		370[e]		
Fluorene		14,000[e]		
Fluoride	4,000			
Guthion				0.01
Heptachlor (c)	0.00260	0.00265	0.52	0.004
Heptachlor epoxide (c)	0.159	1.1	0.52[e]	
Hexachlorobenzene (c)	0.0194	0.0198		
Hexachlorobutadiene (c)	2.99	3.6		
Hexachlorocyclopentadiene		17,000[e]		
Hexachloroethane (c)	84.2	278		
Hexachlorophene	0.0531	0.053		
Indeno(1,2,3-cd)pyrene (c)		0.31[e]		
Isophorone (c)		6,000[e]		
Lead	4.98	25.3[f]	72.6[f,h]	2.52[f,h]
Malathion				0.01
Mercury	0.0122[i]	0.0122[i]	2.4	1.3
Methoxychlor	2.21	2.22		0.03
Methyl bromide		4,000[e]		
2-Methyl-4,6-dinitrophenol		765[e]		
Methylene chloride (c) (Dichloromethane)		16,000[e]		
Methyl ethyl ketone	52,917	9,940,000		
Mirex				0.001
Nickel		4,600[e]	1,415[f,h]	157[f,h]
Nitrate-Nitrogen (as total nitrogen)	10,000			
Nitrobenzene	37.3	233		
n-Nitrosodiethylamine	0.0382	7.68		
n-Nitrosodi-n-butylamine	1.84	13.5		
n-Nitrosodimethylamine (c)		81[e]		
n-Nitrosodiphenylamine (c)		160[e]		
Parathion (ethyl)			0.065	0.013

Table 3-2 *(continued)*

Potential Federal and State Chemical-Specific ARARs for Surface Water Contamination (μg/L or ppb)

Analyte ["(c)" indicates a carcinogen]	Protection of Human Health		Protection of Aquatic Life	
	Texas WQC Freshwater Consumption of Water and Fish[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Consumption of Fish Only[a] [(30 TAC 307.6(d)(1)]	Texas WQC Freshwater Acute Criteria[b,c] [30 TAC 307.6(c)(1)]	Texas WQC Freshwater Chronic Criteria[c,d] [30 TAC 307.6(c)(1)]
PCB-1242, -1254, -1221, -1232, -1248, -1260, -1016				0.014[e]
Total PCBs	0.0013	0.0013	2.0	0.014
Pentachlorobenzene	6.10	6.68		
Pentachlorophenol (c)	1.0	135	20[k]	13[k]
Perchlorate	4[l]			
Phenanthrene			30	30
Phenol		4,600,000[e]		
Pyrene		11,000[e]		
Pyridine	88.1	13,333		
Selenium	50		20[m]	5[m]
Silver (as free ion)			0.8	
1,2,4,5-Tetrachlorobenzene	0.241	0.243		
1,1,2,2-Tetrachloroethane (c)		110[e]		
Tetrachloroethene (c)	5	323		
Thallium		6.3[e]		
Toluene		200,000[e]		
Toxaphene (c)	0.005	0.014	0.78	0.0002
2,4,5-TP [Silvex]	47.0	50.3		
Tributyltin (TBT)			0.13	0.024
1,1,1-Trichloroethane	200	12,586		
1,1,2-Trichloroethane (c)		420[e]		
Trichloroethene (c)	5	612		
2,4,5-Trichlorophenol	953	1,069	136	64
2,4,6-Trichlorophenol (c)		65[e]		
TTHM	100			
Vinyl chloride (c)	2	415		
Zinc			114[f,h]	104[f,h]

Notes and Abbreviations:

[a] *For known or suspected carcinogens, the criteria calculated are based upon an incremental cancer risk level of 1 × 10^{-5}. The "consumption of fish only" WQC are applicable to streams classified as "sustainable fisheries" (defined in 30 TAC 307.3 as those with a stream order of three or greater); if Goose Prairie Creek or other on-site surface waters are determined to be "incidental" rather than "sustainable" fisheries, these numbers may be adjusted to levels more appropriate for "incidental" fisheries.*

[b] *Texas acute criteria do not apply within the ZID, but do apply within a designated mixing zone.*

Table 3-2 *(continued)*
Potential Federal and State Chemical-Specific ARARs for Surface Water Contamination (µg/L or ppb)

Notes and Abbreviations (continued):

[c] *USEPA has issued notice that it intends to revise the aquatic life criteria for copper, silver, lead, cadmium, iron, and selenium, and to develop new criteria for atrazine, diazinon, nonylphenol, MTBE, and manganese (64 FR 58409, October 29, 1999).*

[d] *Texas chronic criteria do not apply within the ZID or within a designated mixing zone; compliance must be achieved at the edge of the mixing zone.*

[e] *These federal AWQC [as listed in 40 CFR 31.36(b)(1)] are potential ARARs* only if there is no state promulgated WQ standard for a particular contaminant. *If a state WQ standard is available, the state standard is legally applicable and takes priority over the federal AWQC; if a state WQ standard is unavailable, the federal AWQC may be relevant and appropriate, depending on site circumstances (USEPA 1989a, 1991). Federal criteria for carcinogens are based upon an incremental cancer risk level of 1×10^{-6} but, per USEPA direction, were recalculated to a risk level of 1×10^{-5} for the purpose of comparison to the Texas risk level of 1×10^{-5} (40 CFR 131.36[b][1], footnote c) USEPA, 1989b.* CERCLA Compliance with State Requirements, *OSWER Directive 9234.2-05FS, Washington, DC, December. USEPA, 1991,* ARARs Q's & A's: General Policy, RCRA, CWA, SDWA, Post-ROD Information, and Contingent Waivers, *OSWER Directive 9234.2-01FS-A, Washington, DC.*

[f] *Criterion is for the dissolved fraction in water; all other criteria are for total recoverable concentrations.*

[g] *This criterion is multiplied by a water-effects ratio to incorporate the effects of local water chemistry on toxicity. The water-effects ratio is equal to 1, except where sufficient data are available to establish a site-specific water-effects ratio. The number preceding the "w" in the freshwater aquatic life criteria equations is an USEPA conversion factor.*

[h] *Value listed here is a site-specific criterion calculated using the equation listed in the regulations, assuming a water-effects ratio of 1 and a default hardness of 100 mg/L as $CaCO_3$.*

[i] *Criterion is expressed as total recoverable and is based on FDA action levels (1 mg/kg) in fish tissue; freshwater BCF = 81,700. USEPA recently issued a new recommended human health water quality criterion of 0.3 mg/kg for methylmercury in fish tissue (66 FR 1344, January 8, 2001) and expects the criterion to be used by states as guidance in establishing or updating their water quality standards.*

[j] *This Texas criterion is for all dioxins/furans.*

[k] *This criterion is expressed as a function of pH using the following equations:* $e^{(1.005(pH)-4.830)}$ *for the acute criterion and* $e^{(1.005(pH)-5.290)}$ *for the chronic criterion; value displayed corresponds to a pH of 7.8.*

[l] *This is a Texas recommended interim drinking water action level (TNRCC Memorandum dated October 5, 2001), not a promulgated WQC. As such, this level would be a TBC rather than an ARAR for setting a final cleanup level and would apply only to Caddo Lake, which is classified as a source of drinking water.*

[m] *Criterion expressed as total recoverable.*

ARAR	*applicable or relevant and appropriate requirement*	*LHAAP*	*Longhorn Army Ammunition Plant*
AWQC	*ambient water quality criteria*	*MTBE*	*methyl tertiary butyl ether*
BCF	*bioconcentration factor*	*OSWER*	*[U.S.] Office of Solid Waste and Emergency Response*
BHC	*benzene hexachloride*	*PCB*	*polychlorinated biphenyl*
$CaCO_3$	*calcium carbonate*	*RCRA*	*Resource Conservation and Recovery Act of 1976*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*	*ROD*	*record of decision*
CFR	*Code of Federal Regulations*	*SDWA*	*Safe Drinking Water Act of 1974*
CWA	*Clean Water Act of 1972*	*TAC*	*Texas Administrative Code*
2,4-D	*dichlorophenoxyacetic acid*	*TBC*	*to-be-considered (guidance)*
4,4-DDD	*dichlorodiphenyldichloroethane*	*TCDD*	*tetrachlorodibenzo-p-dioxin*
4,4-DDE	*dichlorodiphenyldichloroethylene*	*TNRCC*	*Texas Natural Resource Conservation Commission*
4,4-DDT	*dichlorodiphenyltrichloroethane*	*2,4,5-TP*	*2(2,4,5-Trichlorophenoxy)propionic acid*
USEPA	*U.S. Environmental Protection Agency*	*TTHM*	*total trihalomethanes*
FDA	*U.S. Food and Drug Administration*	*WQ*	*water quality*
FR	*Federal Register*	*WQC*	*water quality criteria*
FS	*feasibility study*	*ZID*	*zone of initial dilution*

Table 3-3
Potential Federal and State Chemical-Specific ARARs/TBCs for Groundwater Remediation

Chemical	Federal	State of Texas	
	SDWA MCL[a] (40 CFR 141)	**MCL (30 TAC 290)**	**SMCL (30 TAC 290.118)[b]**
Inorganic Chemicals and Anions (μg/L or ppb)			
Aluminum			50 – 200
Antimony	6	6	
Arsenic	50 (10)[c]	50[c]	
Asbestos	7 MFL	7 MFL	
Barium	2,000	2,000	
Beryllium	4	4	
Cadmium	5	5	
Chloride			300,000
Chromium (total)	100	100	
Copper	TT(1,300)[d]	TT(1,300)[d]	1,000
Cyanide	200	200	
Fluoride	4,000	4,000	2,000
Iron			300
Lead	TT(15)[d]	TT(15)[d]	
Manganese			50
Mercury (inorganic)	2	2	
Nickel	(MCL revoked)	(MCL revoked)	
Nitrate (as N)	10,000	10,000	
Nitrite (as N)	1,000	1,000	
Nitrate + Nitrite (as N)	10,000	10,000	
Selenium	50	50	
Silver	[e]		100
Sulfate	400,000/500,000[f]		300,000
Thallium	2	2	
Zinc			5,000
Organic Chemicals (μg/L or ppb)			
Alachlor	2	2	
Atrazine	3	3	
Benzene	5	5	
Benzo(a)pyrene	0.2	0.2	
Carbofuran	40	40	
Carbon tetrachloride	5	5	
Chlordane	2	2	
Chloroform (TTHM)[g]	80	80	
2,4-D	70	70	
Dalapon	200	200	
Dibromochloropropane	0.2	0.2	
o-Dichlorobenzene	600	600	
p-Dichlorobenzene	75	75	
1,2-Dichloroethane	5	5	
1,1-Dichloroethene	7	7	
cis-1,2-Dichloroethene	70	70	
trans-1,2-Dichloroethene	100	100	
Dichloromethane (Methylene chloride)	5	5	
1,2-Dichloropropane	5	5	
Di(2-ethylhexyl) adipate	400	400	
Di(2-ethylhexyl) phthalate	6	6	
Dinoseb	7	7	
Diquat	20	20	
Endothall	100	100	
Endrin	2	2	
Ethyl benzene	700	700	

Table 3-3 *(continued)*
Potential Federal and State Chemical-Specific ARARs/TBCs for Groundwater Remediation

Chemical	Federal	State of Texas	
	SDWA MCL[a] (40 CFR 141)	MCL (30 TAC 290)	SMCL (30 TAC 290.118)[b]
Ethylene dibromide	0.05	0.05	
Glyphosate	700	700	
Heptachlor	0.4	0.4	
Heptachlor epoxide	0.2	0.2	
Hexachlorobenzene	1	1	
Hexachlorocyclopentadiene	50	50	
Lindane	0.2	0.2	
Methoxychlor	40	40	
Methylene chloride – see Dichloromethane			
Monochlorobenzene	100	100	
Oxamyl (Vydate)	200	200	
Pentachlorophenol	1	1	
Perchlorate		4[h]	
Picloram	500	500	
PCBs	0.5	0.5	
Simazine	4	4	
Styrene	100	100	
2,3,7,8-TCDD (Dioxin)	3×10^{-5}	3×10^{-5}	
Tetrachloroethene	5	5	
Toluene	1,000	1,000	
Toxaphene	3	3	
2,4,5-TP	50	50	
1,2,4-Trichlorobenzene	70	70	
1,1,1-Trichloroethane	200	200	
1,1,2- Trichloroethane	5	5	
Trichloroethene	5	5	
Vinyl chloride	2	2	
Xylenes (total)	10,000	10,000	

Notes and Abbreviations:

[a] *The federal MCLs are relevant and appropriate under the ARARs process for remediation of Class I (potable) groundwater, only if no state MCL is available for a particular contaminant. All federal nonzero MCLGs are equivalent to their respective MCLs and are, therefore, not listed on this table.*

[b] *Texas has promulgated the federal SMCLs into the TAC. The SMCLs are taste and odor, rather than environmental protection, criteria and, as such, do not meet the definition of ARARs; they are included in this table only for initial groundwater screening purposes.*

[c] *Number in parentheses is the new federal MCL for arsenic, as issued January 23, 2001 (66 FR 6976); the effective date of this MCL is February 22, 2002, although compliance with the new MCL is not required until January 23, 2006. Texas has not yet revised their state MCL to match this new, more stringent federal MCL.*

[d] *Number in parenthesis is an "action level" that, if exceeded when measured in the 90th percentile at the consumer's tap, triggers initiation of corrosion control studies and treatment requirements.*

[e] *The interim SDWA MCL for this chemical was revoked and a secondary MCL of 100 μg/L established instead.*

[f] *This is a federal proposed MCL/MCLG only; USEPA has deferred setting a final MCL/MCLG pending further study.*

[g] *Total trihalomethanes refer to the sum of the concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.*

[h] *This is a Texas recommended interim drinking water action level (TNRCC Memorandum dated October 5, 2001), not a promulgated MCL. As such, this level would be TBC guidance, rather than ARAR, for setting a final cleanup level for groundwater classified as drinking water.*

μg/L	*micrograms per liter*
ARAR	*applicable or relevant and appropriate requirement*
CFR	*Code of Federal Regulations*
2,4-D	*dichlorophenoxyacetic acid*
USEPA	*U.S. Environmental Protection Agency*
FR	*Federal Register*
FS	*feasibility study*
LHAAP	*Longhorn Army Ammunition Plant*
MCL	*maximum contaminant level*
MCLG	*maximum contaminant level goal*
MFL	*million fibers per liter*
N	*nitrogen*
PCB	*polychlorinated biphenyl*
ppb	*parts per billion*
SDWA	*Safe Drinking Water Act of 1974*
SMCL	*secondary maximum contaminant level*
TAC	*Texas Administrative Code*
TBC	*to-be-considered (guidance)*
TCDD	*tetrachlorodibenzo-p-dioxin*
TNRCC	*Texas Natural Resource Conservation Commission*
2,4,5-TP	*2(2,4,5-trichlorophenoxy)propionic acid*
TT	*treatment technique*
TTHM	*total trihalomethanes*

Table 3-4
Potential Location-Specific ARARs/TBCs

Resource/Citation	Activity or Prerequisite Status	Requirement
Preservation of Archaeological and Paleontological Artifacts National Historic Preservation Act (16 USC 470 et seq.); 43 CFR 7.5(b)(1); 36 CFR 800; 13 TAC 15; 13 TAC 25	Excavation activities that inadvertently discover such archaeological or paleontological resources**—applicable** if such resources are discovered	Action must avoid irreparable harm, loss, or destruction of such resources if discovered. Such resources must be surveyed, designated, and protected in accordance with relevant federal rules and regulations, standards, and guidelines, as these are adopted by the Texas Historical Commission.
Preservation of Native American Artifacts Native American Graves Protection and Repatriation Act (25 USC Section 3001); 43 CFR 10.4(c) and (d)	Excavation activities that inadvertently discover such Native American resources**—applicable** if such resources are discovered	Activities in the area of the discovery must be stopped and reasonable effort taken to secure and protect the objects discovered.
Protection of Fish and Wildlife Resources **Fish and Wildlife Coordination Act (16 USC 661 et seq.)**	Action that impounds, modifies, diverts, or controls waters, including navigation and drainage activities**—applicable**	The effects of water-related projects on fish and wildlife resources and their habitat should be considered with a view to the conservation of fish and wildlife resources by preventing loss of and damage to such resources.
Protection of Caddo Lake National Wildlife Refuge System National Wildlife Refuge System Act (16 USC 668dd-668ee); 50 CFR 35; 31 TAC 69.19	Activities that may adversely impact or cause harm/loss of protected fish, wildlife and/or habitat in such protected areas**—relevant and appropriate** to impacted areas that will become part of the designated national wildlife refuge system	The taking, disturbance, injury, or damage to any protected plant or animal on a national wildlife refuge is prohibited. The disposal of waste except at designated/approved points or locations or the polluting of any waters, streams, or other areas within any national wildlife refuge is prohibited. Restitution for and/or restoration of fish, wildlife, and habitat loss occurring as a result of human activities is required; appropriate measures include, but are not limited to, direct replacement of fish, wildlife, and/or habitat destroyed.
Protection of Wetlands Section 404 of the Clean Water Act (33 USC 1344); 40 CFR 230.10(a) and (d); Swampbuster Provision of the Food Security Act; Executive Order 11990, “Protection of Wetlands”	Actions that involve the discharge of dredged or fill material into jurisdictional wetlands or actions that have a potential adverse impact to, or take place within, wetlands**—applicable** if delineated wetlands are present at the site and will be adversely impacted by the action	No discharge of dredged or fill material into an aquatic ecosystem is permitted if there is a practicable alternative that would have less adverse impact. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps per 40 CFR 230.70 et seq have been taken, which will minimize potential impacts of the discharge on the aquatic ecosystem.

Table 3-4 *(continued)*
Potential Location-Specific ARARs/TBCs

Resource/Citation	Activity or Prerequisite Status	Requirement
Protection of Floodplains Executive Order 11988 (*Floodplain Management*, May 24, 1997)	Activities which involve federally undertaken, financed, or assisted construction and improvements or which involve conducting federal activities and programs affecting land use—**applicable** if floodplains will be impacted by the remedial action	Action shall be taken to reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and restore and preserve the natural and beneficial values of floodplains. The potential effects of actions in floodplains shall be evaluated, and consideration of flood hazards and floodplain management ensured. If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harm shall be considered.

<u>Abbreviations</u>:

ARAR	*applicable or relevant and appropriate requirement*
CFR	*Code of Federal Regulations*
FS	*feasibility study*
LHAAP	*Longhorn Army Ammunition Plant*
TAC	*Texas Administrative Code*
TBC	*to-be-considered (guidance)*
USC	*United States Code*

Numeric Criteria for Toxic Materials. The standards set numeric criteria levels in 30 TAC 307.6 for toxic materials for the protection of human health and the protection of aquatic life based on the classified use of the water body. Human health criteria for a domestic water supply (Table 3, Column A in 30 TAC 307.6) apply to freshwater that is designated or used for public drinking water supplies. The criteria prevent contamination of drinking water, fish, and other aquatic life to ensure that they are safe for human consumption (30 TAC 307.6[d][2][A]). Typically, the criteria are set at levels equivalent to the federal/state Safe Drinking Water Act MCLs (30 TAC 290) for those chemicals for which MCLs are available. The criteria specified in Table 3, Column A in 30 TAC 307.6, apply to Caddo Lake (into which LHAAP surface waters drain), whose designated uses include contact recreation, high quality aquatic life, and public water supply (30 TAC 307.10, Appendix A). The criteria in Table 3, Column B of 30 TAC 307.6, designed to prevent contamination of fish and other aquatic life to ensure they are safe for human consumption, apply to freshwaters that have "sustainable fisheries" and are not designated as a public drinking water supply (30 TAC 307.6[d][B]). Sustainable fisheries are defined in 30 TAC 307.3(56) as streams that potentially have sufficient fish production or fishing activity to create significant long-term human consumption of fish and that have a stream order of three or greater. If any of the on-site surface waters are classified as “incidental” rather than sustainable fisheries, which is more likely based on observed aquatic life levels in these streams, the numeric criteria for ingestion of organisms must be adjusted to a more appropriate level for an incidental fishery.

The regulations also include freshwater acute and chronic numeric criteria (30 TAC 307.6[c], Table 1) for the protection of aquatic life. The acute criteria are applicable to all water in the state except for small zones of initial dilution at discharge points; the chronic criteria are applicable to all water in the state with designated or existing aquatic life uses, except inside mixing zones and below critical low-flow conditions, in accordance with 30 TAC 307.8 (30 TAC 307.6[c][6]).

Application of Water Quality Standards. Water quality standards are implemented through enforceable National Pollutant Discharge Elimination System (NPDES) permits for point source discharges and through the implementation and maintenance of best management practices for non-point source discharges (USEPA, 1994b). Section 131.12(a)(2) of the Clean Water Act of 1972 (CWA) regulations leaves it to the states to determine when controls on non-point sources are needed to attain state water quality standards (USEPA, 1994b).

Contaminants present in groundwater at LHAAP-67 may migrate toward and discharge into Central Creek. If the seepage occurs over a diffuse area of a stream bank rather than from a discrete point source, the seep would likely be considered a non-point source discharge. USEPA guidance states that contaminated groundwater that naturally flows into surface waters is not considered a point source discharge (USEPA, 1988a).

Numeric acute toxicity criteria are applied as 24-hour averages, chronic toxicity criteria are applied as 7-day averages, and human health criteria are applied as long-term average exposure criteria designed to protect populations over a lifetime of 70 years (30 TAC 307.9[e][4]).

Aquatic life criteria are applicable to samples collected at any depth; human health criteria are applicable to the average concentration from the surface to the bottom. Samples collected at approximately 1 foot below the water surface are also acceptable for comparison to numerical criteria for purposes of standards attainment (30 TAC 307.9[c][4]). Specific numeric human health criteria do not apply at stream flows below the harmonic mean flow (defined as “a measure of mean flow in a water course which is calculated by summing the reciprocals of the individual flow measurements, dividing this sum by the number of measurements, and then calculating the reciprocal of the resulting number”) (30 TAC 307.8[a][8]). General narrative criteria (30 TAC 307.4) apply in all waters, including mixing zones and below-critical low-flow conditions (30 TAC 307.4[a]). Numeric criteria do not apply if the background concentrations of specific toxins in waters exceed the criteria values (30 TAC 307.6[c][10][A]).

Assessment of compliance with the Texas Water Quality Standards is addressed in 30 TAC 307.9 (*Determination of Standards Attainment*). This section of the state regulation refers to the latest approved version of the *TNRCC Guidance for Screening and Assessing Texas Surface and Finished Drinking Water Quality Data* for evaluation of collected samples. The latest version of this guidance (TNRCC, 2000) describes the following general process for conducting a compliance assessment: Individual values for each parameter are compared to either numerical water quality criteria or screening levels, and the percentage of all values in exceedance is computed. The percent exceedance is then compared to categorical ranges, and 0–10 percent exceedances are considered “criteria support” (i.e., compliance with the standards).

Use Classifications. The surface water quality standards in 30 TAC 307 must be met in waters of the state depending on the site-specific classifications for the particular waters or segments of waters (as listed in 30 TAC 307.10, Appendices A–E). None of the streams at LHAAP have been officially designated as yet under the state’s site-specific use classification process, but Caddo Lake (into which LHAAP surface waters drain) has been designated for contact recreation, high-quality aquatic life, and public water supply (30 TAC 307.10, Appendix A).

The regulations set out a series of presumptions concerning aquatic life uses for unclassified waters. In addition to aquatic life uses, unclassified waters can be assigned uses for contact and non-contact recreation as well as domestic water supply. Recreational use is assigned to all waters based on the indicator bacteria of fecal coliform (30 TAC 307.7[b][1]). Recreational use can be assigned for either contact or non-contact recreation. Domestic water supply consists of two use subcategories: public water supply and aquifer protection (30 TAC 307.7[b][2]). Uses that are not attainable throughout the year are still assigned and protected for the portions of the year where such uses are attainable (30 TAC 307.4[l]).

For unclassified water bodies, such as LHAAP surface waters, the water body (or bodies) can be designated by the TNRCC for uses that are attainable or characteristic of the water body (30 TAC 307.4[l]); the water uses for the classified segment are then listed in 30 TAC 307.10, Appendix A. TNRCC also has the authority pursuant to the federal CWA to amend the narrative standards, designated uses, and numeric criteria to adopt a site-specific standard for a specific surface water that reflects local conditions (30 TAC 307.2[d]). A site-specific standard requires amendment of the regulations, including a public hearing/notice and a process that includes site-specific studies and a use attainability analysis, which demonstrates that reasonable attainable uses are protected (30 TAC 307.2[d][3]).

Numeric criteria that are potential ARARs for LHAAP surface water streams are listed in **Table 3-2**. The criteria listed in **Table 3-2** for the protection of human health from consumption of water and fish would apply to Caddo Lake, which is classified as a domestic water supply as measured at a state-designated point of compliance. No LHAAP surface waters are currently classified as a domestic water supply. The human health criteria from consumption of "fish only" would be ARARs only if Central Creek or other on-site surface waters were considered "sustainable" fisheries, which is doubtful. As defined in 30 TAC 307.3, sustainable fisheries are water bodies that potentially have sufficient fish production or fishing activity to create significant long-term human consumption of fish. It is anticipated that Central Creek represents an "incidental" rather than "sustainable" fishery (i.e., it supports aquatic life but not to the levels of sustainable fishery waters). The numeric criteria listed in **Table 3-2** would, therefore, need to be adjusted pursuant to 30 TAC 307.6(d)(6) to numbers equivalent to 10 times the criteria (i.e., an order of magnitude less stringent) for application to Central Creek. The criteria that apply to the protection of aquatic life are also ARARs for LHAAP surface waters. For those chemicals lacking a Texas numeric criterion, the federal AWQC, are listed in the table and footnoted as such (see **Section 3.2.2.1.2** for a discussion of federal AWQC as ARARs). In the absence of state or federal criteria, numerical criteria may be derived in accordance with 30 TAC 307.6(c)(7) for aquatic life and 30 TAC 307.6(d)(8) for human health.

Antidegradation. The Texas antidegradation policy (30 TAC 307.5), which applies to any actions that would increase the pollution of water in the state, requires that existing uses and water quality sufficient to protect those existing uses be maintained (30 TAC 307.5[b][1]) and disallows any activities subject to regulatory action that would cause degradation of waters. Texas defines degradation as a lowering of water quality by more than a de minimis extent but not to the extent that an existing use is impaired (30 TAC 307.5[b][2]).

The surface water quality standards and antidegradation policies discussed here are ARARs for non-point source seep discharges into LHAAP surface waters, assuming application of the standards as discussed here at a negotiated point of compliance.

3.2.2.1.2 Federal Ambient Water Quality Criteria

The federal AWQC, as listed in 40 CFR 131.36(b)(1) (USEPA Section 304[a] *Criteria for Toxic Pollutants*) are potential ARARs for surface water. The federal AWQC are typically incorporated by individual states into promulgated water quality standards for individual surface water bodies in the state. A state promulgated standards then become the legally applicable standards for these surface water bodies. CERCLA Section 121(d)(2)(A) and the NCP at 40 CFR 300.430(e)(2)(i)(E) specifically state that remedial actions shall at least attain federal AWQC if they are "relevant and appropriate under the circumstances of the release." If there is no Texas water quality standard for a particular contaminant but there is a federal AWQC available, the federal AWQC would be considered relevant and appropriate for that particular contaminant. Federal AWQC are included in **Table 3-2** and footnoted as such if there is no state standard available for a particular contaminant.

3.2.2.2 Chemical-Specific ARARs for Groundwater

Data from the RI field activities indicate that contaminants have leached into the underlying groundwater at LHAAP-67 and that remediation of the groundwater to achieve chemical-specific ARARs may be necessary as a component of this response action. Chemical-specific ARARs and TBCs for groundwater remediation include the federal and State of Texas public drinking water system standards; these are listed in **Table 3-3** and discussed below. The State of Texas has no promulgated groundwater quality standards that limit the concentration of particular chemical constituents in groundwater based upon classification.

3.2.2.2.1 State/Federal Safe Drinking Water Act standards

Federal sources of potential ARARs are the MCLs (40 CFR 141.12, 141.61, and 141.62) and the nonzero maximum contaminant level goals (MCLGs) (40 CFR 141.50 and 141.51) under the federal Safe Drinking Water Act. The federal drinking water standards are typically incorporated by individual states into their promulgated water quality standards for public water supply systems in the state. A state's promulgated standards (as listed under 30 TAC 290, Subchapter F for Texas) then become the legally applicable standards, as measured at the tap, for these systems and are administered by the state under a USEPA-authorized program. The NCP at 40 CFR 300.430(e)(2)(i)(B) and (C) states that federal MCLGs set at levels above zero may be relevant and appropriate requirements for contaminants in groundwater determined to be a current or potential source of drinking water. If an MCLG is determined not to be relevant and appropriate (based upon criteria listed in 40 CFR 300.400[g][2]) or the MCLG is set at zero, the corresponding MCL is the cleanup standard for such groundwater where the MCL is relevant and appropriate under the circumstances of the release.

The groundwater at LHAAP is not officially classified, either pursuant to promulgated Texas regulations or under the Texas Groundwater Protection Committee's unpromulgated groundwater classification system as a Class I (potable) groundwater resource or a public water supply system. As discussed above, however, the NCP states that the federal and state MCLs and nonzero MCLGs may be relevant and appropriate requirements if the groundwater is used as a source of drinking water. The groundwater at the installation could be considered potable resource water since it is used as drinking water by on-site industrial workers, thus invoking MCLs as potential ARARs for groundwater remediation. Pursuant to USEPA guidance (1989a), where USEPA has delegated to a state the authority to implement a federal program, the state regulations replace the equivalent federal requirements as the potential ARARs. **Table 3-3** lists the state of Texas promulgated MCLs. The federal MCLs are also listed in the event that no state standard is available for a particular contaminant. All federal nonzero MCLGs for these contaminants are identical to the MCLs and are, therefore, not listed in **Table 3-3**. Texas has no promulgated MCLGs.

The federal proposed MCLs, proposed nonzero MCLGs, and secondary MCLs are sources of potential TBCs. Secondary drinking water standards are unenforceable federal guidelines regarding taste, odor, color, and certain other aesthetic effects of drinking water that are recommended to the states by USEPA as reasonable goals for drinking water. Texas has promulgated the federal secondary MCLs in 30 TAC 290.118 as secondary maximum constituent levels applicable to all public water systems. Secondary MCLs are not environmental protection criteria that meet the definition of ARARs or TBC guidance. They are listed in **Table 3-3**, however, for initial groundwater screening purposes. The federal proposed MCLs and nonzero MCLGs, considered TBC guidance, are also included in **Table 3-3** and footnoted as such.

3.2.3 Location-Specific ARARs

This section identifies the location-specific ARARs that may apply to LHAAP-67. These ARARs are summarized in **Table 3-4**.

3.2.3.1 Prehistoric and Historic Archaeological Sites and Paleontological Resources

A total of 1,484 acres at LHAAP were initially intensively surveyed for cultural resources (USACE, 1992). An additional 1,931 acres were excluded from the survey because of previous ground disturbances. The installation's remaining 5,073 acres still required surveying. An initial survey was completed by USACE (USACE, 1992) to record the archaeological sites and historic cemeteries at LHAAP. Several archaeological sites and three historic cemeteries were recorded during this initial survey. Additional archaeological sites were identified during subsequent surveys and classified based on documentation contained in three reports: Geo-Marine, 1996, Gadus et al., 1998, and Pertulla and Nelson, 1999. A total of twenty-seven (27) archaeological sites have been determined to possess the necessary attributes to make them eligible for protection or inclusion in the National Register of Historic Places (NRHP). Additionally, the Cultural Resources Management Plan (Geo-marine, 1996) stated that 24 archivally identified sites were at LHAAP. Cemeteries are not considered eligible for the NRHP but are protected under Texas law (see below).

Before intrusive investigation activities began at LHAAP, all of the investigation areas were surveyed for historical sites and/or artifacts, and a letter of approval from the Texas State Historic Preservation Officer (SHPO) was received before each investigation. No investigative plans had to be altered due to the presence of historic or archaeological sites.

In the event that significant archaeological or paleontological resources are discovered during remedial action activities at LHAAP-67, the federal National Historic Preservation Act (16 USC 470 et seq.) and Texas regulations for the protection of archaeological and cultural resources (13 TAC 15 and 13 TAC 25) would provide location-specific ARARs. These ARARs are included in **Table 3-4** to address this contingency. Texas regulations require that such discovered resources be surveyed, designated, and protected in accordance with relevant federal rules, regulations, standards, and guidelines.

Although highly unlikely, in the event that any historic cemeteries are discovered at LHAAP-67, certain provisions of Title 8, Texas Health and Safety Code, Chapters 711–715, may provide location-specific ARARs. For example, if an unknown or abandoned cemetery is discovered, Chapter 711.010 prohibits further construction or activity until the disturbed human remains are removed. Because the existence of cemeteries at LHAAP-67 is highly unlikely, cemetery protection laws are not included as location-specific ARARs in **Table 3-4**. If such resources are discovered during further investigation of these sites, the cemetery protection laws will be re-evaluated as ARARs in future decision documents.

3.2.3.2 Traditional Resources

A preliminary survey for significant Native American resources within the boundary of LHAAP has been conducted and indicates the presence of Native American resources on the property. Members of the Caddo Lake Indian Tribe have visited LHAAP, attended meetings, and expressed interest in and concern for the Native American resources on the site. In addition, discussions were held about establishing Native American educational displays covering the historical aspects of LHAAP property. The federal Native American Graves Protection and Repatriation Act (25 USC Section 3001) and its implementing regulations (43 CFR 10.4[c]) are location-specific ARARs for the protection of such resources. These regulations require that activities in any area where such resources are discovered be stopped and reasonable effort be taken to secure and protect the objects discovered.

3.2.3.3 Historic Structures

As discussed in **Section 3.2.3.1**, a cultural resources survey conducted in 1992 identified 16 archeological sites and 3 historic cemeteries at LHAAP, 7 of which were determined ineligible for inclusion on the National Register of Historic Places (the remaining 9 determinations are pending). Although there is a high probability that additional historic properties are present (more than a dozen historic house-sites remain to be discovered), it is considered unlikely that any of these properties would be located at LHAAP-67. It is assumed, therefore, that neither the federal National Historic Preservation Act (16 USC 470 et seq.) nor the Texas cultural resource protection regulations relative to buildings or structures are location-specific ARARs for this action.

3.2.3.4 Threatened and Endangered Species

The area surrounding LHAAP contains habitat identified as suitable for five federal and/or state threatened species (CLI, 1995). Of the five animal species that could potentially be present, information received from USFWS (2003) and Texas Department of Parks and Wildlife (2003) identified the following species known or suspected to occur in the vicinity of LHAAP:

- **Federal Listed Threatened Species:**
  - Bald Eagle
  - Louisiana Black Bear

- **State Listed Threatened Species:**
  - Louisiana Black Bear
  - Alligator Snapping Turtle
  - Bluehead Shiner

- **State Species of Concern:**
  - Southern Lady's Slipper

- **State Special Features/Natural Communities/Managed Areas:**
  - Colonial Waterbird Rookeries
  - Bald Cypress-Water Tupelo Series
  - Shortleaf Pine-Oak Series
  - Water Oak-Willow Oak Series
  - Caddo Lake State Park

LHAAP-67 consists of wooded and grassy vegetated areas. No designated critical habitat for federally-listed threatened or endangered species is present at LHAAP-67 (USFWS, 2005). The only state-listed threatened or endangered species that has been confirmed at LHAAP is the Alligator Snapping Turtle, which is an aquatic turtle that lives in sloughs and deep muddy pools. No permanent water bodies are present within the site; therefore, LHAAP-67 does not contain habitat suitable for the Alligator Snapping Turtle. Thus, because the habitat present at LHAAP-67 does not support federal- or state-listed threatened or endangered species, location specific ARARs for the protection of such species are not necessary for this site.

3.2.3.5 Sensitive Habitats

A sensitive habitat is defined within the CERCLA hazard ranking system (40 CFR 300, Appendix A) as one that contains an important biological resource or a particularly fragile resource. Wetlands are specifically included as a type of sensitive habitat. Other sensitive habitats include plant communities of unusual or limited distribution and important seasonal-use areas for wildlife (e.g., migration routes, breeding areas, or crucial winter habitat).

Although there are low-lying wetland areas associated with Goose Prairie Creek, Central Creek, Saunder’s Branch, and Harrison Bayou, no formal wetlands survey has been specifically conducted at LHAAP or at LHAAP-67 specifically (USACE 1992; Jacobs 2001). Nearby Caddo Lake, however, into which LHAAP surface waters flow is part of the Big Cypress Bayou, which is considered a wetland of international significance. Adverse impacts to any identified wetlands located at LHAAP-67 or to the Caddo Lake/Big Cypress Bayou wetland system from remedial actions at LHAAP-67 must be avoided to the extent practicable and would require compensation. Compensation, if needed, could be made by enhancing or creating wetlands at a nearby mitigation site, thus meeting the substantive requirements of Section 404 of the federal CWA (33 USC 1344), the Swampbuster provision of the federal Food Security Act, and Executive Order 11990, “Protection of Wetlands,” as implemented through 40 CFR 230.10. If identified wetlands will be impacted and wetland mitigation is required, Title 12, Chapter 221 (*Wetlands Mitigation*) of the Texas Code, as well as the federal standards for wetland mitigation, may provide location-specific ARARs. These requirements will be evaluated during the final ROD stage as further site-specific data are collected and the preferred alternative is proposed and evaluated.

The Fish and Wildlife Coordination Act (16 USC 661 et seq.) requires that the effects of water-related projects that modify, divert, or control waters, including drainage activities, be considered with a view to preventing loss of and damage to such resources. This act may provide ARARs if groundwater diversion or treatment activities will impact groundwater-to-surface-water drainage patterns such that fish or wildlife may be adversely affected.

In October 2000, the USFWS, entered into a cooperative agreement with the Army, designating LHAAP as part of the Caddo Lake National Wildlife Refuge for migratory birds and other fish and wildlife management, conservation, and protection. The USFWS administers the National Wildlife Refuge System, in accordance with the National Wildlife Refuge System

Administration Act of 1966 (16 USC 668dd–668ee), through its regulations under 50 CFR Subchapter C, Parts 25–35. The Caddo Lake National Wildlife Refuge is administered cooperatively by the USFWS and the Texas Parks and Wildlife Department. In accordance with 31 TAC 69.19, Texas is required to seek full restitution for and/or restoration of fish, wildlife, and habitat loss occurring as a result of human activities. Appropriate restitution and restoration measures include, but are not limited to, direct replacement of fish, wildlife, and/or habitat destroyed or payments equal to the monetary value of the destroyed resources (31 TAC 69.19). These requirements may be ARARs if wetlands or other sensitive habitats are identified at LHAAP-67 and if losses of fish, wildlife, or habitat occur as a result of remediation activities at LHAAP-67.

3.2.3.6 Floodplains

Executive Order 11988 *(Floodplain Management*, May 24, 1997) requires evaluation of potential effects of actions in floodplains, consideration of flood hazards, and that floodplain management is ensured. If action is taken in floodplains, the order requires consideration of alternatives that avoid adverse effects and incompatible development and minimize potential harm. This order, as summarized in **Table 3-4**, is TBC guidance for LHAAP-67 remedial activities if such activities should impact identified floodplains.

3.3 Preliminary Remediation Levels

The RAO for LHAAP-67 is to prevent human exposure to contaminated groundwater in excess of the target risk range and an HI of 1 for the future maintenance worker under an industrial scenario and to prevent potential site groundwater impacts to nearby surface water bodies such that ARARs are met. This RAO allows a range of response actions. For a response action that leaves contamination in place, land use controls would be needed in combination with the response action in order to prevent exposure. For a response action that removes the contamination, remediation levels would be needed to determine when sufficient contamination has been removed. Remediation levels are the concentrations for individual chemicals in groundwater above which remediation or control measures would be required. The remediation levels for LHAAP-67 are determined with consideration of the risk to human health and the ARARs identified for the site. Remediation levels are provided for groundwater only, as it was the only medium at LHAAP-67 presenting an unacceptable risk or hazard to human health under an industrial scenario.

Groundwater with an unacceptable risk or hazard is present at LHAAP-67 primarily due to 1,1-DCE. The following contaminants were also detected in groundwater at concentrations exceeding their respective MCLs: 1,1-DCE, 1,2-DCA, 1,1,1-TCA, 1,1,2-TCA and TCE. All five of these aforementioned contaminants are considered COCs within this FS because they exceed their respective MCLs in groundwater. Based on the anticipated future use of the facility (i.e., a wildlife refuge), LHAAP groundwater will not likely be used in the future as a drinking water source. However, to be conservative, groundwater remediation levels are based on a future industrial scenario, which includes limited ingestion of groundwater. To meet drinking water standards for an industrial worker (not domestic use), the preliminary remediation levels for the COCs in groundwater are set equal to their respective MCLs. **Table 3-5** shows the concentrations equating to the preliminary groundwater remediation level for each of the COCs exceeding their respective MCLs in LHAAP-67 groundwater. After remediation, MCL comparisons will be performed to verify that the remediation levels have been achieved throughout the plume.

Additionally, the COCs present in groundwater beneath LHAAP-67 could also potentially discharge to surface water in Central Creek located to the southeast of the site, which flows to Caddo Lake, a drinking water source. Although plume migration modeling indicates that the COCs in groundwater would not discharge to surface water at such levels that ARARs are exceeded in Central Creek, the potential for groundwater impact to surface water is addressed within this FS.

Table 3-5
Maximum Contaminant Levels for LHAAP-67 Groundwater Contaminants

Groundwater Contaminant	Maximum Concentration (µg/L)	MCL (µg/L)
1,1,1-Trichloroethane	1800	200
1,1,2-Trichloroethane	33	5
1,1-Dichloroethene	380	7
1,2-Dichloroethane	27	5
Trichloroethene	6.3	5

Abbreviations:

MCL	*maximum contaminant level*
µg/L	*micrograms per liter*

4.0 Identification and Screening of Technologies and Process Options

The primary objective of identifying, screening, and evaluating potentially applicable technology types and process options for the LHAAP-67 FS is to identify an appropriate range of remedial technologies and process options to be developed into remediation alternatives. This screening process consists of a series of analytical steps that include the following:

- Identify volumes or areas of media of concern, and COCs **(Section 4.1)**
- Identify GRAs **(Section 4.2)**
- Identify and screen remedial technologies and process options **(Section 4.3)**
- Evaluate and select representative process options **(Section 4.4)**

These steps are outlined in the USEPA RI/FS guidance (USEPA, 1988b) and the NCP.

4.1 Contaminants and Media Volumes of Concern

Section 2.0 presents the detailed site conditions at LHAAP-67. Based on available sampling data, groundwater at LHAAP-67 has been identified as the medium of concern because it poses an unacceptable carcinogenic risk and non-carcinogenic hazard to an industrial worker, primarily due to the presence of 1,1-DCE at a maximum concentration of 380 μg/L. Additional chlorinated compounds detected in LHAAP-67 groundwater above their respective MCLs include 1,1,1-TCA, 1,1,2-TCA, 1,2-DCA, and TCE **(Figure 2-2)**. These five contaminants are identified as COCs due to the exceedance of their respective MCLs in groundwater. The COCs were detected above their respective MCLs in three wells screened within the shallow groundwater zone and located within the vicinity of the aboveground storage tanks formerly located at LHAAP-67.

The most restrictive MCL for any of the COCs is 5 μg/L for TCE; therefore, a total COC concentration limit of 5 μg/L was selected as a conservative basis for determining the horizontal and vertical extent of groundwater requiring remedial action at LHAAP-67. Based on the 5 μg/L total COC concentration limit, the approximate areal extent of groundwater contamination requiring remedial action at LHAAP-67 is 300,000 square feet. The COCs at LHAAP-67 were detected in the shallow groundwater. The shallow groundwater aquifer can vary in thickness across the site. Assuming the aquifer to be homogenous across the site, an aquifer thickness of 15 feet was used to conservatively estimate the total volume of groundwater requiring remedial action. The total volume of groundwater requiring remedial action was calculated based on the following equation:

$$\begin{aligned}&\mathit{Areal\ extent\ of\ groundwater\ contam.}\,(300{,}000\,\mathit{sq\ ft}) \quad\times\quad \mathit{vertical\ extent\ of}\\ &\mathit{groundwater\ contam.}\,(15\,\mathit{ft}) \quad\times\quad \mathit{total\ porosity}\,(0.345) \quad\times\quad 7.48\ \mathit{gallons\ per\ cubic\ foot}\\ &= \quad 11{,}781{,}000\,\mathit{gallons}\end{aligned}$$

Therefore, the volume of groundwater requiring remedial action equals approximately 11.78 million gallons.

4.2 General Response Actions

General response actions (GRAs) are large groups of remedial actions that typically satisfy the RAO. The GRAs include no action, land use controls, monitored natural attenuation (MNA), containment, removal, treatment, and disposal. These GRAs may be combined to form remediation alternatives that meet the RAO. The following are descriptions of the GRAs:

- **No Action**—The no action GRA is retained throughout the FS process as required by the NCP. The no action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative no remedial action will be taken. The site is considered to be left "as is," with no land use controls, containment, removal, treatment, or other mitigating actions.

- **Monitored Natural Attenuation**—MNA is defined in the NCP as "biodegradation, dispersion, dilution, and adsorption" of contaminants that allow remediation levels to be reached in a reasonable time frame. MNA is usually combined with other GRAs, such as land use controls or containment.

- **Land Use Controls**—Land use controls include access controls or deed restrictions that would reduce or eliminate access to the site. The volume, mobility, and toxicity of the contaminants are not reduced through the application of institutional actions. Land use controls are generally combined with other GRAs to meet the RAO.

- **Containment**—Another method of reducing risk to receptors is through containment, which reduces access to the contaminated medium or the migration potential of the contaminated medium. The contaminated medium must be isolated from the primary transport mechanisms such as groundwater flow. This isolation may be accomplished through the installation of subsurface barriers.

- **Removal**—Removal technologies extract the contaminated medium from its present location and move it to an alternative location for treatment and/or disposal. These removal technologies can be selected to reduce exposure to workers and can be amenable to treatment processes.

- **In-Situ Treatment**—In-situ treatment technologies or process options reduce the toxicity, mobility, or volume of the contaminated medium. Chemicals are added, physical properties of the medium are changed, or biological activity of the medium is modified without removal.

- **Ex-Situ Treatment**—Ex-situ treatment process options involve the reduction of toxicity, mobility, or volume of contaminated medium. Ex-situ treatment processes are typically coupled with removal and disposal process options.

- **Disposal**—Disposal process options involve the discharge of the contaminated medium. Disposal process options are typically coupled with removal and treatment process options.

4.3 Screening of Process Options

This section presents the approach to technology and process option screening. In the technology screening process, GRAs are identified that, by themselves or in combination with other GRAs, could be implemented to meet the RAO established for LHAAP-67. Technologies associated with each response action and process options associated with each technology are identified. Process options that are not technically feasible for the site are eliminated (screened out) from further consideration. If all of the process options under a given technology are screened out, the entire technology is eliminated.

The technologies and process options are initially screened for technical applicability to identify those to be carried forward for further evaluation. The screening process reduces the number of possible process options for a given technology to a number that is appropriate for consideration at LHAAP-67. The following are the two general criteria used to determine if a technology or process option should be retained for further evaluation:

- Applicability to the type and combination of contaminants
- Applicability to the site's physical conditions

Figure 4-1 presents the technologies and process options considered for LHAAP-67 groundwater. Process options not considered technically applicable were not retained for further evaluation; the rationale for their elimination is shown in this figure.

4.4 Evaluation and Selection of Representative Process Options

In this section, each of the process options retained from the initial screening in **Section 4.3 (Figure 4-1)** are further evaluated and screened, further reducing the list of process options that are developed into alternatives in **Section 5.0**. Process options are evaluated using three criteria: effectiveness, implementability, and cost. Based on these criteria, representative process options are selected for each technology. The representative process options provide a basis for developing alternatives in the FS.

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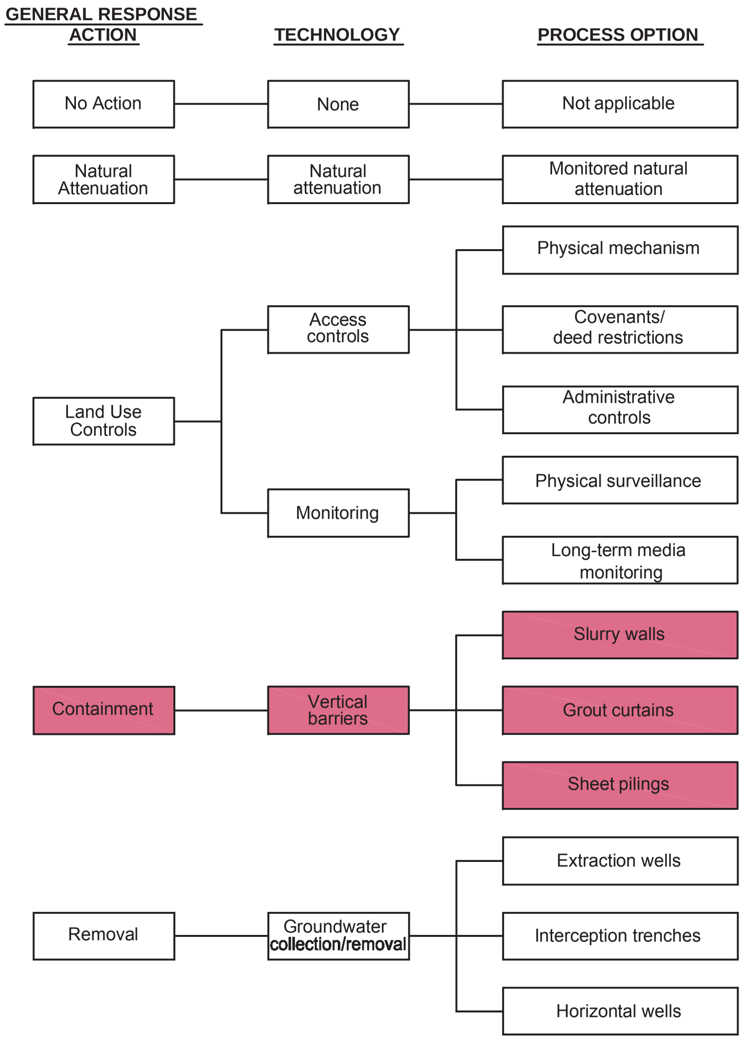
IMAGE	X–REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
.	–––	*Houston, Texas*	*J. RDZ*	*4/18/04*	*J. MALINO*	*4/19/04*	*P. SRIVASTAV*	*5/28/04*	845714–A21T



GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
No Action	None	Not applicable		Required for consideration
Natural Attenuation	Natural attenuation	Monitored natural attenuation	The monitored degradation of contaminants through natural biological and chemical processes	Potentially applicable
Land Use Controls	Access controls	Physical mechanism	Maintain/Install signs to limit access to contaminated areas	Potentially applicable
		Covenants/ deed restrictions	Restricts land use by codes, deeds or zoning	Potentially applicable
		Administrative controls	Use of training, procedures, etc., to limit access to contaminated areas	Potentially applicable
	Monitoring	Physical surveillance	Inspection of engineered remedial actions and maintenance to ensure proper operation of engineered controls	Potentially applicable
		Long-term media monitoring	Long-term groundwater monitoring used to determine effectiveness of remedial actions	Potentially applicable
Containment	Vertical barriers	Slurry walls	Soil/bentonite-filled trench to control or divert groundwater flow	Not applicable; no bottom barrier to key into
		Grout curtains	Chemical or cement-based grout injected in a series of overlapping columns to form a barrier to groundwater flow	Not applicable; no bottom barrier to key into
		Sheet pilings	A subsurface barrier to groundwater flow constructed by inserting overlapping steel panels into the ground	Not applicable; no bottom barrier to key into
Removal	Groundwater collection/removal	Extraction wells	Groundwater extraction wells designed to remove contaminated groundwater	Potentially applicable
		Interception trenches	Trench filled with permeable media used to intercept and collect shallow groundwater	Potentially applicable to shallow, dissolved phase
		Horizontal wells	Wells installed horizontally beneath a waste area to collect groundwater and leachate	Potentially applicable

🟥 Process option screened out

☐ Process option retained

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FIGURE 4–1 (1 OF 2)
GROUNDWATER TECHNOLOGY SCREENING
FEASIBILITY STUDY, LHAAP–67, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

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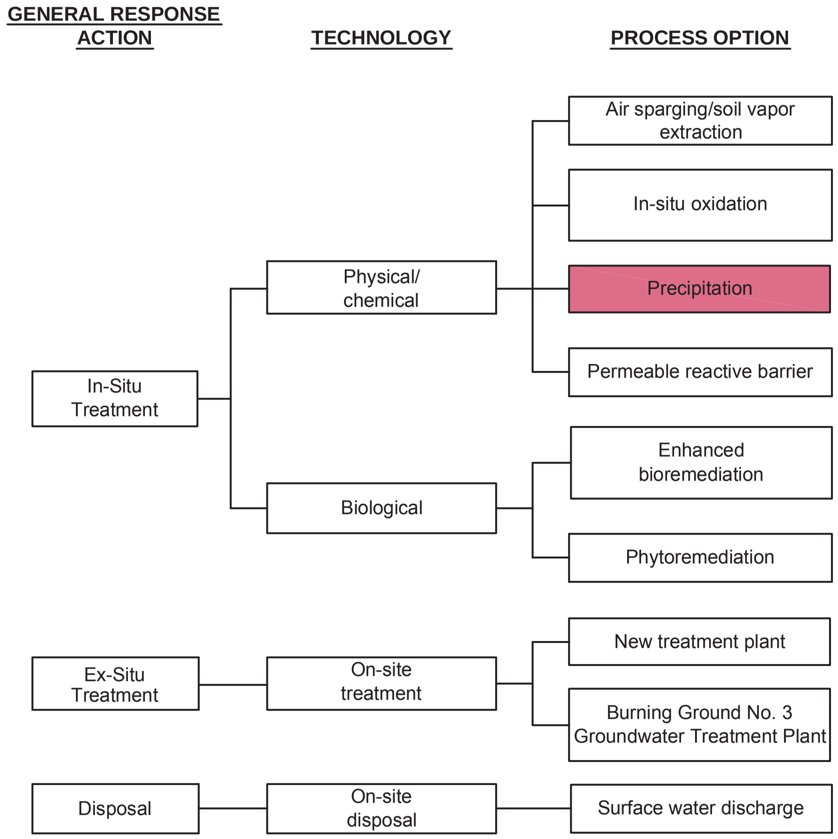
Plot Date/Time: 05/24/04 09:34am
Plotted by: colette.agabiti

IMAGE	X–REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
.	–––	*Houston, Texas*	*J. RDZ*	*4/18/04*	*J. MALINO*	*4/19/04*	*P. SRIVASTAV*	*5/28/04*	845714–A22T



PROCESS OPTION	DESCRIPTION	SCREENING COMMENTS
Air sparging/soil vapor extraction	Air injected into groundwater and vadose zone to remove contaminants through volatilization; organic laden air is extracted for ex-situ treatment	Potentially applicable to dissolved phase VOCs
In-situ oxidation	Chemical oxidants added in-situ to convert organics to less toxic form	Potentially applicable
Precipitation	Injection of chemicals that cause contaminants to precipitate in place	Not applicable to VOCs
Permeable reactive barrier	A trench filled with a reactive or sorbent material designed to treat groundwater as it passes through the trench	Potentially applicable to dissolved VOCs
Enhanced bioremediation	Microbes and nutrients are injected into the subsurface to biologically degrade organics	Potentially applicable to VOCs
Phytoremediation	Plants are used to remove, transfer, stabilize, or destroy contaminants	Potentially applicable to dissolved phase VOCs
New treatment plant	Mobile or skid-mounted system near extraction point	Potentially applicable
Burning Ground No. 3 Groundwater Treatment Plant	Treatment processes at existing water treatment plant are precipitation, air stripping, and fluidized bed reactor	Potentially applicable
Surface water discharge	Discharge of treated groundwater to surface water	Potentially applicable after treatment

🟥 Process option screened out

☐ Process option retained

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FIGURE 4–1 (2 OF 2)
GROUNDWATER TECHNOLOGY SCREENING FEASIBILITY STUDY, LHAAP–67, GROUP 4

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

The general descriptions of the process options retained from the screening, along with the relevant aspects of effectiveness, implementability, and cost, are discussed. The effectiveness evaluation considers the following: (1) the potential effectiveness of process options in handling the estimated areas or volumes of the medium; (2) the contribution toward meeting any of the goals identified in the RAO; (3) the potential impacts to humans and the environment during the construction and implementation phase; and (4) how proven and reliable the process is with respect to the contaminants and conditions at the site.

The implementability evaluation considers both the technical and administrative feasibility of implementing a process option. Technical implementability concentrates on the difficulty of implementing the option, including the number of treatability studies required, the extent of innovative design required, and the extent of site preparation needed. Unusual equipment or unusual conditions for standard equipment may decrease the ease of implementation. The institutional aspects of implementability such as permitting and availability of services are also considered.

The cost evaluation focuses on the relative capital and operation and maintenance (O&M) costs required. A ranking of high, medium, or low relative to other similar process options is given, each ranking considering both capital and O&M costs. Based on this evaluation, one or more representative process options are selected for each response action to be carried forward into the development of alternatives. The selection of representative process options for the development of alternatives does not eliminate the remaining process options from future consideration. Those process options not carried forward may be reconsidered during the development of the proposed plan, ROD, or remedial design.

4.4.1 Groundwater

4.4.1.1 No Action

The no action GRA provides no groundwater remedial activities. No monitoring of the groundwater or surface water conditions occurs under this GRA. This GRA is retained as a baseline with which other remediation alternatives are prepared.

- **Effectiveness**— A lack of access controls or remediation of the groundwater from LHAAP-67 could result in a future unacceptable risk to humans if the groundwater is ingested.
- **Implementability**—No implementation is required.
- **Cost**—None.

4.4.1.2 Monitored Natural Attenuation

Natural subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions with subsurface materials are monitored to confirm their progress in reducing contaminant concentrations to acceptable levels over time. Although the degree of natural attenuation occurring at LHAAP has not been established, the types of contaminants found at LHAAP-67 (chlorinated compounds) are amenable to this technology.

- **Effectiveness**—MNA is considered under CERCLA on a case-by-case basis. USEPA guidance has been developed to aid in the selection of this process option for VOCs. MNA has been selected for a number of CERCLA sites. It is effective when source term releases have been mitigated and a determination is made that natural attenuation is occurring and that further off-site releases are not occurring at unacceptable levels. Regular monitoring must be conducted throughout the process to confirm that attenuation is occurring in accordance with cleanup objectives. Although the potential effectiveness of MNA at LHAAP-67 has not been established, cis-1,2-DCE (a common degradation product of TCE) and vinyl chloride (a common degradation product of TCE, 1,1-DCE, and 1,1,1-TCA) were not detected in the shallow groundwater. The lack of the degradation products may be an indicator that natural attenuation is not occurring at LHAAP-67.

- **Implementability**—Significant groundwater sampling and analyses must be performed to confirm that conditions are suitable for natural attenuation and to establish a monitoring network. It must also be confirmed that additional source releases and unacceptable off-site releases are not occurring.

- **Cost**—Low to moderate.

4.4.1.3 Land Use Controls

Land use controls include covenants/deed restrictions, long-term groundwater monitoring, and physical surveillance. This GRA controls risk by removing the receptor from the source of the risk and also provides information needed to assess future conditions at the site. All land use control process options are applicable to the groundwater at LHAAP-67.

4.4.1.3.1 Access Controls

Access controls would be implemented to regulate access to the groundwater. The process options for access controls include covenants/deed restrictions and administrative controls.

Covenants/Deed Restrictions. Restrictions to the groundwater can be accomplished through modifications to the property deed or agreements about land use. Legal restrictions can be placed on the installation of groundwater extraction wells not only to prevent access to the contamination but also to minimize the chance of moving the contamination toward a future user. Deed restrictions would be needed prior to transfer of the property to a non-federal entity.

These restrictions are only effective as long as the property owners and local authorities enforce them. The Army is ultimately responsible for the enforcement of the land use controls.

- **Effectiveness**—Covenants/deed restrictions are effective, if enforced, in controlling human activities such as potable well construction. These actions can limit or prevent exposure to contaminants remaining on the site after remediation and can be implemented on a temporary basis.
- **Implementability**—These options can be readily implemented.
- **Cost**—Low.

Administrative Controls. Administrative controls consist of the use of training or procedures to limit access to the site and reduce the risk to human health posed by site contamination at LHAAP-67. These measures may include internal notices and site inspections to serve as a reminder of the existence of land use controls, a site approval process to review land-use changes at LHAAP-67 to ensure the land use controls are followed, training of site personnel regarding the existence and care of the land use controls, and regular inspection and maintenance of the land use controls. These are controls the Army can use while they maintain control of the site.

- **Effectiveness**—Administrative controls are effective in controlling human intrusion into contaminated areas during and after remediation. The training required for access to the site limits potential exposure to the contaminated groundwater. Administrative controls can be used in conjunction with physical mechanisms and deed restrictions. This option is effective only while land use controls are maintained.
- **Implementability**—Training and procedures are readily available and implemented. They may need to be modified for LHAAP.
- **Cost**—Low.

Physical Mechanisms. Physical mechanisms include various engineered remedies to contain or reduce contamination and/or physical barriers intended to limit access to property, such as fences or signs. Fencing at LHAAP-67 would be impractical due to the size of the groundwater plume.

- **Effectiveness**—Physical mechanisms are effective in controlling human intrusion into contaminated areas during and after remediation. This option is only effective as long as the physical mechanisms are maintained.
- **Implementability**—This option is readily implemented, as warning signs are commercially available items. Existing warning signs are already being used at LHAAP.
- **Cost**—Low.

4.4.1.3.2 Monitoring

Monitoring and surveillance are used to assess the performance of remedial actions and verify compliance with the established RAO. Process options for monitoring are physical surveillance and long-term media monitoring.

Physical Surveillance. Visual and physical inspections of engineered remedial action components can detect physical changes (e.g., iron deposition and pipeline cracks) that may ultimately lead to the failure or unsatisfactory performance of that component. Repairs and/or revised maintenance activities can be implemented as a result of these inspections.

- **Effectiveness**—Physical surveillance is effective in determining the continued integrity of engineered systems and the need for repairs and/or replacement. Physical surveillance needs to be used with contaminant monitoring to assess the impact of integrity failure.
- **Implementability**—Physical surveillance is easily implemented and requires experienced, but readily available personnel to make regular visits to the site for inspections.
- **Cost**—Low.

Long-Term Media Monitoring. Environmental media (e.g., groundwater) can be monitored after the implementation of the remedial action to determine the effect the remedy has had on the level of contamination. Long-term media monitoring can detect a potential failure of the action to meet the RAO. Monitoring can also be used to detect changes in expected site conditions or changes in the expected effectiveness of the remedy, and indicate whether additional actions should be implemented.

- **Effectiveness**—Long-term media monitoring would be successful in evaluating the effectiveness of a remedial alternative. The effectiveness of the monitoring system depends on the design of the monitoring plan.
- **Implementability**—Equipment and personnel are readily available. The site is readily accessible, and most monitoring techniques have already been implemented at LHAAP. Multiple groundwater-monitoring wells are already in place, and there is a reasonable baseline of groundwater conditions.
- **Cost**—Moderate due to labor and analytical costs.

4.4.1.3.3 Summary of Land Use Controls Process Options

Covenants/deed restrictions, administrative controls, physical mechanisms, physical surveillance, and long-term media monitoring are carried forward as representative process options for the land use controls GRA. The covenants/deed restrictions would only be used if the Army releases the land to a non-federal entity. All of these process options could be combined with other process options to meet the RAO.

4.4.1.4 Removal

The removal GRA consists of technologies that remove groundwater to either relocate it or prepare it for treatment. The removal technology considered is groundwater collection/removal.

4.4.1.4.1 Groundwater Collection/Removal

Groundwater collection and removal is accomplished by either extraction wells, interception trenches, or horizontal wells.

Extraction Wells. These are vertically installed wells designed to collect and extract clean or contaminated groundwater to contain a plume or to reduce contaminant mass in the plume. Extraction wells have been used with mixed results at LHAAP.

- **Effectiveness**—Extraction wells are considered the most effective groundwater removal technology applicable over a wide range of site conditions. However, proper locations need to be selected to provide for effective extraction. The low yield from many existing extraction wells at LHAAP limits the effectiveness of this process option.

- **Implementability**—This process is the single most commonly used method to remove groundwater in a very wide range of conditions. Some site predesign characterization may be needed to site new wells. Extraction wells are easy to install at depths required to intercept all depths of groundwater. Existing monitoring wells at LHAAP-67 could be converted to extraction wells.

- **Cost**—Low to moderate.

Interception Trenches. An interception trench is a high permeability subsurface trench that collects contaminated groundwater. It is constructed and operates very much like a vertical French drain with the exception that the collected groundwater is actively pumped from the trench for ex-situ treatment. The trench can be installed across the entire width of a shallow plume to more effectively capture contaminated groundwater.

- **Effectiveness**—Interception trenches are very effective at collecting groundwater. The trench functions like a continuous line of extraction wells. The trenches are also only applicable to shallow zone contamination.

- **Implementability**—Interception trenches are relatively easy to install with conventional construction equipment. The process requires long-term maintenance to ensure that the permeable media and collection piping do not become clogged. Interception trenches are difficult to install at depths to intercept the intermediate flow zone.

- **Cost**—Moderate.

Horizontal Wells. Horizontal wells are similar to vertical wells with the exception that the horizontal wells are installed horizontally and are typically screened their entire length. They function like drains and offer a water removal capability that exceeds that of a similarly sized vertical well. Horizontal wells could be installed under source areas to remove contaminated groundwater or collect migrating leachate.

- **Effectiveness**—Horizontal wells are very effective at removing large volumes of contaminated groundwater in applications where vertical wells cannot be used. Wells up to 12 inches in diameter and 10–500 feet deep can be installed over 1,000-foot lengths. A single horizontal well is generally equivalent to five vertical wells in sandy soil and ten vertical wells in clayey soil.
- **Implementability**—Although this process is commonly used in the oil industry, it is still in the demonstration phase in environmental restoration. It would likely be used underneath a source area to collect contaminated groundwater or leachate.
- **Cost**—High.

4.4.1.4.2 Summary of Removal Process Options

Horizontal wells are not retained as a representative groundwater removal process option because of their limited use in environmental restoration actions and because of their high costs. Interception trenches are also effective at removing groundwater though typically at a higher cost than extraction wells. Because extraction well systems are flexible, robust, and effective in a wide range of hydrogeologic conditions, the extraction well process option will be retained for remedial alternative development in this FS. However, interception trenches could be considered during the implementation of the remedial action, should the results of pre-design studies warrant their use.

4.4.1.5 In-Situ Treatment

In-situ treatment technologies provide varying levels of groundwater treatment without prior removal of the groundwater, and reduce the mobility or toxicity of the contaminants in groundwater. The in-situ treatment technologies under consideration are physical/chemical and biological treatments.

4.4.1.5.1 Physical/Chemical Treatment

Air sparging/soil vapor extraction, in-situ oxidation, and permeable reactive barriers are process options considered potentially applicable to the groundwater at LHAAP-67.

Air Sparging/Soil Vapor Extraction. This process option is designed to remove VOCs from the groundwater by volatilizing these contaminants through the introduction of air. Air is introduced into the groundwater, assisting in the volatilization of those organics in solution in the groundwater. Extraction wells are installed into the vadose zone and a vacuum is drawn on these wells. The extraction system draws off the organic-laden air that was bubbled through the groundwater in addition to any vapors that exist in the soil pore spaces. The volatilized contaminants can then be drawn from these extraction wells and treated. This process can be used in those areas where VOCs exist in the groundwater and the vadose zone above this groundwater is relatively permeable.

- **Effectiveness**—This process is very effective on highly volatile contaminants (e.g., 1,1-DCE) and highly permeable formations. It is incompatible with certain soil types, and high humic content inhibits volatilization of contaminants. High clay content soil, however, may limit the effectiveness of air sparging by retarding the movement of air and vapors through the soil column. Implementation at LHAAP-67 is complicated by the nonhomogeneous geology found at the site. The presence of discontinuous high-permeability zones can result in preferential air flow paths, limiting the effectiveness.

- **Implementability**—Vapor extraction and air sparge equipment is readily available, and commercial vendors are available to design and operate these systems. This process has been used at many hazardous waste sites in relatively homogeneous media. Organics that are removed from the vapor extraction wells require ex-situ treatment. Site characterization and modeling are required to determine the proper location of the injection and extraction wells and extraction rates.

- **Cost**—Low to moderate.

In-Situ Oxidation. Contaminated media are treated through the addition of oxidizers, such as potassium permanganate or hydrogen peroxide, which convert the contaminants to a less mobile or toxic form. This process option is applicable to VOCs such as 1,1-DCE and TCE.

- **Effectiveness**—In-situ oxidation is effective on contaminants in a relatively homogeneous and porous medium. Long-term effectiveness is uncertain as a change in chemistry could mobilize or change the chemical behavior of the previously oxidized or reduced constituents. Chemical oxidation is most effective for VOCs (particularly TCE). Chemical oxidation is not effective for treatment of chlorinated alkanes such as those detected in LHAAP-67 groundwater (1,1,1-TCA, 1,1,2-TCA and 1,2-DCA).

- **Implementability**—This process option may be difficult to implement in situ because of concerns regarding delivery and sufficient exposure of the contaminants to the chemical agents. An additional concern is the release of excess reactants or byproducts to the environment. There have been limited applications of these processes, which are generally more readily implemented in the ex-situ mode. A recent USEPA evaluation by their Technology Innovation Office concluded that the application of in-situ oxidation is highly dependent upon the delivery system.

- **Cost**—Low to moderate.

Permeable Reactive Barriers. Permeable reactive barriers can be a physical/chemical or biological treatment option. A reactive barrier or gate is a permeable wall containing reactive media that is constructed across the path of a contaminant plume. As contaminated water passes through the wall, the contaminants are removed or degraded, allowing uncontaminated water to emerge on the downgradient side. Reactive barriers are usually installed through adaptation of conventional construction methods for impermeable barriers such as open trenches, polymer slurry trenches, and overlapping caissons. Reactive barriers may be constructed from a variety of materials including zero-valence metals (ZVM), granulated activated carbon (GAC), biological material, and other sorbents. These materials treat contaminants through a combination of mechanisms, including adsorption, chemical reduction, and biodegradation.

ZVM works by chemically reducing contaminants, thus either causing their degradation or limiting their mobility. A variety of metals can be used as reducing agents such as silver, gold, palladium, copper, zinc, aluminum, manganese, and iron. In-situ reactive gates require high volumes of ZVM, making the application of precious metals such as silver, gold, and palladium impractical. The most practical metal for this technology is iron, because of its relative abundance, low cost, and low toxicity. However, more expensive yet more effective forms of iron (palladized iron) may be necessary, depending on the contaminant.

GAC is the most widely used adsorbent and filter medium because of its effectiveness on a variety of contaminants. GAC is chemically stable and will not produce secondary contaminants. The surface area of the carbon and the pH of the solution flowing through the medium determine the rate and effectiveness of GAC in adsorbing contaminants. In addition, different contaminants are adsorbed according to different ionic natures and kinetics.

An innovative in-situ biological permeable reactive barrier at the Naval Weapons Industrial Reserve Plant in McGregor, Texas, has reduced TCE levels in groundwater below detection levels. The biological system consists of trenches filled with highly permeable reactive material along with carbon sources from organic materials such as compost, vegetable oil, and cottonseed.

- **Effectiveness**—The effectiveness of this process depends greatly on the contaminants, the reactive media, site hydrology, and site geochemistry. Reactive media clogging and exhaustion causes the need for periodic replacement. The gates are generally limited to shallower applications because of the difficulties in installing and monitoring the media at depth. There are concerns over the longevity of the reactive media given uncertain and changing chemical and physical conditions. There is evidence from trenches installed at Oak Ridge National Laboratory that the chemistry of VOC degradation is proven; however, the hydraulics can become the limiting factor in the effectiveness of these trenches. For instance, clay smearing resulting from sheet pile removal is thought to change the hydraulics of a trench at the Denver Federal Center (McMahon, et al., 1999).

- **Implementability**—Permeable reactive barriers require adequate site and contaminant characterization and monitoring to determine effectiveness. This process requires treatability testing before full-scale implementation to determine potential physical and chemical interactions with surrounding materials, location within the aquifer, and criteria for replacement. Long-term maintenance requirements may be significant.

- **Cost**—Low to moderate.

4.4.1.5.2 Biological Treatment

Biological treatment process options use living organisms such as bacteria or fungi to detoxify or immobilize contaminants in waste. These process options are applied primarily to convert organic contaminants into nontoxic products.

Enhanced Bioremediation. This general process option covers a wide range of individual biological process options that rely on microbial transformation of organic contaminants under aerobic or anaerobic conditions into benign forms to obtain energy or carbon. Enhanced biodegradation is applicable to the groundwater at LHAAP-67. Excessively high concentrations of contaminants could be toxic to microbes. Many organic contaminants, including the COCs at LHAAP-67, can be biodegraded under anaerobic (without oxygen) conditions. The activity of microorganisms is greatly affected by pH, redox potential, temperature, oxygen content, and most importantly, nutrient availability. These conditions can be manipulated to achieve optimal conditions for microbial activity, accelerating the biodegradation of the target contaminants. The conditions are manipulated through the addition of nutrients or electron acceptors or donors.

- **Effectiveness**—In-situ biodegradation is effective in either low oxygen conditions or high oxygen and methane conditions in a permeable media that enhances the continuing delivery of nutrients to the bacteria. The primary challenge for in-situ biological treatment is to effectively introduce the bacteria and nutrients to the affected areas and ensure adequate mixing and contact. The rate of destruction is typically slower than other competing processes, but fewer and less toxic byproducts result. Pilot-scale testing has demonstrated that some enhancements will allow indigenous bacteria to degrade chlorinated solvents such as those detected at LHAAP-67.

- **Implementability—**Enhancing the biological activity may be difficult in some of the low permeability soil at LHAAP-67 because of complications associated with the delivery of nutrients and oxygen. Equipment and expertise are readily available, but significant treatability testing would be required.

- **Cost—**Low to moderate.

Phytoremediation. Phytoremediation is an emerging technology that uses plants to control contaminant releases from soil or water. It is only applicable to contamination present in the shallow zone, and it may be effective for treatment of VOCs. Phytoremediation processes can be classified based on the contaminant fate: degradation, extraction, containment, or a combination of these. Phytoremediation mechanisms include extraction of contaminants from groundwater; concentration of contaminants in plant tissue; degradation of contaminants by biotic or abiotic processes; volatilization or transpiration of volatile contaminants from plants to the air; immobilization of contaminants in the root zone; hydraulic control of contaminated groundwater (plume control); and control of runoff, erosion, and infiltration by vegetative covers. Poplar and cottonwood trees have been successfully used to remove and degrade TCE from groundwater.

- **Effectiveness—**It has been demonstrated that TCE is effectively removed by phytodegradation or the uptake and breakdown of contaminants by metabolic processes. Hybrid poplar trees were exposed to water containing 50 ppm TCE and metabolized the TCE within the tree. Plant uptake is controlled by hydrophobicity, solubility, and polarity. Toxic intermediates or degradation products may be formed.

- **Implementability—**Time is required for the deeper-rooted trees to grow sufficiently to provide an effective remedy. The contamination depth, even in the shallow zone, would require deeper-rooted plants. This is a fairly easy process option to implement.

- **Cost—**Low to moderate.

4.4.1.5.3 Summary of In Situ Treatment Process Options

There are numerous in-situ groundwater treatment process options available. The physical/chemical treatment process options will not be retained for remedial alternative development. The effectiveness of the physical/chemical process options for treatment of LHAAP-67 groundwater may be limited by site geology or hydraulic conditions, contaminant characteristics, or the degree of required long-term maintenance. Phytoremediation is eliminated from further consideration due to the significant time required for treatment and depth of contamination. Enhanced bioremediation is retained for remedial alternative development. This process option is expected to be effective for the contaminants at LHAAP-67 (e.g., 1,1-DCE, TCE, 1,1,1-TCA, 1,1,2-TCA and 1,2-DCA) and will produce less toxic byproducts than other competing processes.

4.4.1.6 *Ex Situ Treatment*

Ex-situ treatment technologies provide varying levels of water treatment following extraction or collection of the water. These technologies are applied to reduce the volume, mobility, or toxicity of recovered groundwater. Although ex-situ treatment technologies considered are physical/chemical, thermal, and biological, they have been grouped into two process options under an on-site treatment technology – the existing treatment system and a new mobile or skid-mounted system near the extraction point.

4.4.1.6.1 *New Treatment Plant*

A small, skid-mounted or mobile treatment plant could be built near the point of groundwater extraction. The treatment system would be designed for removal of the COCs from the extracted groundwater. GAC or air stripping could remove the COCs. The new treatment plant may require a pretreatment system (e.g., precipitation) if iron and other interfering metals are present in the groundwater.

- **Effectiveness**—The new system could be very effective. All of the considered technologies are proven effective and are even used at an existing treatment plant at LHAAP. Smaller units have less operational flexibility and may expect deviations more often. However, this option would be effective.
- **Implementability**—The implementation of this option is more difficult than that of the existing treatment plant. A few studies would be needed to design the plant to meet the site conditions. This option is still reasonably easy to implement.
- **Cost**—Moderate. The capital costs of this option are considerably greater than that of the existing plant. However, there is a potential that the operational costs could be minimized.

4.4.1.6.2 *Burning Ground No. 3 Groundwater Treatment Plant*

Process wastewater and decontamination water are sent to the LHAAP groundwater treatment plant. This facility, which is currently processing contaminated groundwater from other LHAAP sites, includes unit operations such as neutralization, precipitation, biological digestion, and air stripping. The effluent from the plant is discharged to Harrison Bayou.

- **Effectiveness**—The existing facility is currently treating groundwater. The hydraulic capacity of the plant has not been met yet, so additional flow could be effectively handled. The discharge requirements are routinely met, indicating an effective operation.

- **Implementability**—The treatment plant is already operational. It is operating below current design capacity. Depending on the composition of the site water sent to the plant, it is possible that no revisions to the plant would be necessary.
- **Cost**—Low.

4.4.1.6.3 Summary of Ex-Situ Treatment Process Options

The existing Burning Ground No. 3 groundwater treatment plant is retained for remedial alternative development. It is already effectively operational, and the capital costs have already been spent. Currently, groundwater from other LHAAP sites provides the majority of the water that is treated by the plant. Because of its proven effectiveness and lower costs, the current treatment system is used to develop alternatives.

4.4.1.7 Disposal

The representative on-site disposal process option evaluated is surface water discharge.

4.4.1.7.1 Surface Water Discharge

This process option discharges treated wastewater into a surface water body, stream, or river. This would require piping and pumps or a gravity drain system to transport the treated water to the surface water discharge point. The treated wastewater would likely be discharged into a local surface water body. Currently, the existing treatment plant discharges into Harrison Bayou.

- **Effectiveness**—This process option is an effective method for disposal of water if the requisite NPDES discharge limits can be met. The current treatment system discharges to Harrison Bayou through an NPDES-monitored point.
- **Implementability**—Discharge limits have already been selected for the current discharge point. The existing water treatment plant is currently discharging through this point; therefore, this process option would be easily implemented.
- **Cost**—Low.

4.4.1.7.2 Summary of Disposal Process Options

The surface water discharge process option is retained for remedial alternative development. This process option has already been implemented for the existing treatment plant.

4.4.1.7.3 *Summary of Representative Process Options*

Figure 4-2 is presented to illustrate the process options that have been selected for remedial alternative development. The following remedial alternatives are developed from the retained representative GRAs, technologies or process options:

- Alternative 1 – No Action
- Alternative 2 – Land Use Controls
- Alternative 3 – In-situ Bioremediation, Land Use Controls (short term)
- Alternative 4 – Groundwater Extraction, On-site Treatment, Surface Water Discharge, and Land Use Controls (short term)

Detailed analyses of these remedial alternatives are included in **Section 5.0**.

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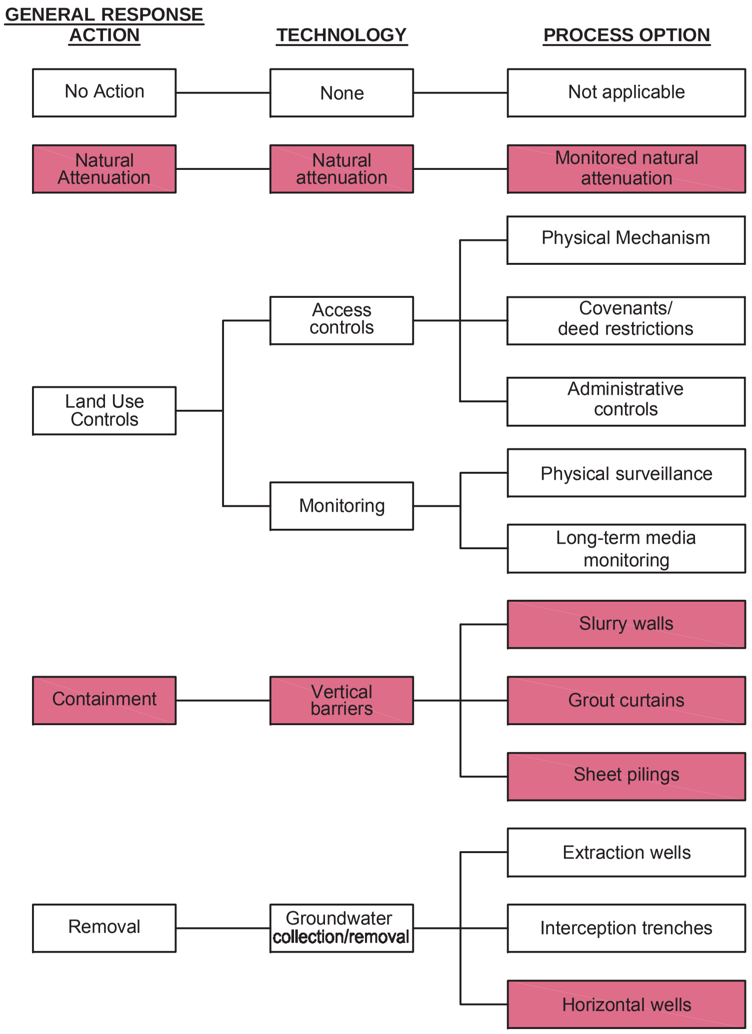
IMAGE	X–REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
.	---	Houston, Texas	J. RDZ	4/10/04	J. MALINO	4/19/04	P. SRIVASTAV	5/28/04	845714–A23T



PROCESS OPTION	DESCRIPTION	SELECTION COMMENTS
Not applicable		Required for consideration
Monitored natural attenuation	The monitored degradation of contaminants through natural biological and chemical processes	Significant monitoring requirements and no detection of degradation products (cis-1,2-DCE and vinyl chloride)
Physical Mechanism	Maintain/Install signs to limit access to contaminated areas	Potentially applicable
Covenants/ deed restrictions	Restricts land use by codes, deeds or zoning	Potentially applicable
Administrative controls	Use of training, procedures, etc. to limit access to contaminated areas	Potentially applicable
Physical surveillance	Inspection of engineered remedial actions and conduct of maintenance to ensure proper operation of engineered controls	Potentially applicable
Long-term media monitoring	Long-term groundwater monitoring used to determine effectiveness of remedial actions	Potentially applicable
Slurry walls	Soil/bentonite-filled trench to control or divert groundwater flow	Not applicable; no bottom barrier to key into
Grout curtains	Chemical or cement-based grout injected in a series of overlapping columns to form a barrier to groundwater flow	Not applicable; no bottom barrier to key into
Sheet pilings	A subsurface barrier to groundwater flow constructed by inserting overlapping steel panels into the ground	Not applicable; no bottom barrier to key into
Extraction wells	Groundwater extraction wells designed to remove contaminated groundwater	Potentially applicable
Interception trenches	Trench filled with permeable media used to intercept and collect shallow groundwater	Potentially applicable. Could be considered after predesign studies are conducted.
Horizontal wells	Wells installed horizontally to collect groundwater and leachate	High cost and limited use in environmental restoration

🟥 Process option screened out

☐ Process option retained

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FIGURE 4–2 (1 OF 2)
SELECTION OF REPRESENTATIVE GROUNDWATER PROCESS OPTIONS
FEASIBILITY STUDY, LHAAP–67, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

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Plotted by: colette.agabiti

IMAGE	X–REF	OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
.	---	Houston, Texas	J. RDZ	4/18/04	J. MALINO	4/19/04	P. SRIVASTAV	5/28/04	845714–A24T

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SELECTION COMMENTS
In-Situ Treatment	🟥 Physical/ chemical	🟥 Air sparging/soil vapor extraction	Air injected into groundwater vadose zone to remove contaminants through volatilization; Organic ladden air is extracted for ex-situ treatment	Difficult to implement due to nonhomogeneous geology found at the site
		🟥 In-situ oxidation	Chemical oxidants added in-situ to convert organics to less toxic form	Not effective for treatment of chlorinated alkanes
		🟥 Precipitation	Injection of chemicals that cause contaminants to precipitate in place	Not applicable to VOCs
		🟥 Permeable reactive barrier	A trench filled with a reactive or sorbent material designed to treat groundwater as it passes through the trench	Significant long-term maintenance requirements
	⬜ Biological	⬜ Enhanced bioremediation	Microbes and nutrients are injected into the subsurface to biologically degrade organics	Potentially applicable
		🟥 Phytoremediation	Plants are used to remove, transfer, stabilize, or destroy contaminants	Signifcant time required for treatment
Ex-Situ Treatment	⬜ On-site treatment	🟥 New treatment plant	Mobile or skid-mounted system near extraction point	More costly and difficult to implement as compared to existing treatment plant
		⬜ Burning Ground No. 3 Groundwater Treatment Plant	Treatment processes at existing water treatment plant are precipitation, air stripping, and fluidized bed reactor	Potentially applicable
Disposal	⬜ On-site disposal	⬜ Surface water discharge	Discharge of treated groundwater to surface water	Potentially applicable after treatment

🟥 Process option screened out

⬜ Process option retained

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FIGURE 4–2 (2 OF 2)
SELECTION OF REPRESENTATIVE
GROUNDWATER PROCESS OPTIONS
FEASIBILITY STUDY, LHAAP–67, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

5.0 Development and Description of Alternatives

Section 5.1 presents the development of a range of alternatives based on the key assumptions regarding site and contaminant conditions **(Section 2.0)**, the RAO **(Section 3.0)**, and the representative process options **(Section 4.0)**. **Section 5.2** presents the detailed description of the alternatives, and **Section 5.3** lists the action-specific ARARs.

5.1 Development of Alternatives

5.1.1 Requirements and Preferences

The CERCLA process, as defined in the NCP, develops a remedy that protects human health and the environment, complies with ARARs (unless a statutory waiver is justified and granted), is cost-effective, and uses permanent solutions and alternative treatment or resource recovery technologies to the maximum extent practicable. A statutory preference for remedies that would result in permanent and significant decreases in toxicity, mobility, or volume through treatment and provide long-term protection is stated in Section 121 of CERCLA, as amended.

The NCP defines the following preferences in developing remedial action alternatives:

- Use of treatment to address the “principal threats” posed by a site, wherever practical.
- Use of engineering controls, such as containment, for waste that poses a relatively low, long-term threat and for which treatment is not practical.
- Implementation of a combination of actions, as appropriate, to achieve protection of human health and the environment. For example, in appropriate site situations, treatment of principal threats would be combined with engineering controls, such as containment, and land use controls for treatment residuals and untreated waste.
- Use of land use controls, such as drinking water supply controls and deed restrictions, to supplement engineering controls for short- and long-term management to prevent or limit exposures to hazardous substances.
- Selection of an innovative technology when the technology offers the following: the potential for comparable or better treatment performance or implementability, fewer or lesser magnitude adverse impacts than other technologies, or lower costs than demonstrated technologies for similar levels of performance.
- Usable groundwater is expected to be returned to beneficial uses, whenever practicable, within a time frame that is reasonable given the particular circumstances of the site. When such restoration is not practicable, the

prevention of further migration of the plume and of exposure to the contaminated groundwater are expected.

These statutory requirements and preferences were given due consideration in the development of alternatives for LHAAP-67.

5.1.2 Development using Remediation Strategies and Process Options

The medium at LHAAP-67 presenting an unacceptable risk or hazard is groundwater. Thus, the purpose of the remedial alternatives is to present the decision maker with technical and economic options for remediating the contaminated groundwater at LHAAP-67. Although all of the action alternatives would achieve the RAO and the statutory requirements under CERCLA, each alternative must also be sufficiently unique in its strategy and approach that the range of alternatives represents a reasonable spectrum of final site conditions in the view of the decision makers.

The remedial technologies and associated process options that were carried forward from the initial screening performed in **Section 4.0** are used to form remedial alternatives for the groundwater at LHAAP-67. Specifically, **Figure 4-2** highlights the process options selected to represent each technology type. A detailed analysis of these alternatives is included in **Section 6.0**. The four alternatives to be considered for detailed analysis include the following:

- Alternative 1 – No Action
- Alternative 2 – Land Use Controls
- Alternative 3 – In-situ Bioremediation, Land Use Controls (short term)
- Alternative 4 – Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (short term)

The NCP requires that a “No Action” alternative (Alternative 1) be evaluated as a comparative baseline. The strategy of this alternative is to “walk away” from the site and cease any existing remediation efforts or land use controls.

5.1.3 Access Controls and Monitoring Common to Alternatives 2, 3, & 4

Because groundwater contamination would be left in place indefinitely at LHAAP-67 for Alternative 2 and would be present for the duration of remedial activities in Alternatives 3 and 4, land use controls are common to these three action alternatives. The land use controls will focus on preventing future long-term use of the groundwater. The controls used to prevent groundwater use would likely include the following:

- **Covenants/Deed Restrictions**—Legal restrictions would be made to a property deed if contaminated property were transferred to a non-government owner. These restrictions (e.g., drilling restrictions, residential/agricultural land use restrictions, drinking water well restrictions) would prohibit or restrict property uses that may result in exposure to contaminated groundwater. Property notices and maps of known residual contamination would be filed with local authorities.
- **Administrative Controls**—Minimization of worker exposure to on-site contamination would be achieved through training and other administrative procedures that control or otherwise limit the activities of workers and maintenance personnel at LHAAP-67 to prevent access to contaminated groundwater.
- **Physical Mechanisms**—Physical mechanisms include various engineered remedies to contain or reduce contamination and/or physical barriers intended to limit access to property, such as fences or signs. Warning signs could be posted at LHAAP-67 to provide notification that groundwater usage in the area is restricted due to groundwater contamination and that the installation of potable water wells is prohibited.

Alternatives 2, 3, and 4 also include the following surveillance and long-term media monitoring activities:

- **Physical Surveillance**—Scheduled periodic inspections would be performed to assess the condition of engineered features (e.g., monitoring or extraction wells, pipelines, treatment plants). Systematic inspection and documentation protocol would be followed. Any cracking or other damage to engineered components would be repaired as required.
- **Groundwater Monitoring**—Monitoring wells would be sampled routinely to monitor the migration of contaminants in groundwater. Monitoring would be continued as required to demonstrate compliance with ARARs and the RAO and in support of CERCLA 5-year reviews. Additional monitoring requirements unique to a particular alternative are addressed in the detailed description of that alternative.

5.2 Description of Remedial Alternatives

The following sections describe the remedial alternatives developed in the previous sections. The level of detail presented here supports the detailed evaluation and cost estimate in **Section 6.0** and **Appendix A**, respectively.

5.2.1 Alternative 1 – No Action

As required by the NCP, the no action alternative provides a comparative baseline against which the action alternatives can be evaluated. Under this alternative, the groundwater would be left "as is" without implementing any additional containment, removal, treatment, or other mitigating actions. No other actions would be implemented to reduce existing or potential future exposure to human and ecological receptors.

5.2.2 Alternative 2 – Land Use Controls

The goals of this alternative are to protect the industrial worker by preventing exposure to contaminated groundwater at LHAAP-67, and to monitor the migration of the groundwater contaminant plume and its potential impact to Central Creek. To accomplish these goals, land use controls would be maintained to prevent human exposure to groundwater presenting an unacceptable risk to human health through access controls (e.g., deed restrictions, administrative controls or physical security). Sampling of two existing monitoring wells and two newly installed monitoring wells would also be conducted to monitor the migration of the contaminant plume to ensure that the COCs in groundwater do not migrate to Central Creek at such levels that ARARs are exceeded.

Long-term operational requirements under this alternative would be minimal, and would involve maintenance of the land use controls and the monitoring activities discussed in **Section 5.1.3**. Groundwater sampling and analysis would be performed at LHAAP-67 for multiple contaminants and general chemistry parameters. Groundwater sampling would occur quarterly for the first two years and annually for years three through five. Monitoring would continue as required to demonstrate compliance with ARARs and the RAO and in support of the 5-year reviews required by CERCLA Section 121 (c). If sampling results show unusual trends or perturbations, the data would be evaluated to determine the course of action.

5.2.3 Alternative 3 – In-situ Bioremediation, Land Use Controls (short term)

The goals of this alternative are to achieve MCLs for the COCs throughout the groundwater contaminant plume at LHAAP-67 and to prevent human exposure to groundwater contamination until the MCLs are achieved. To achieve these goals, this alternative utilizes in-situ bioremediation to reduce groundwater contaminant concentrations to the MCLs, and maintains land use controls only until such time that the MCLs are met for groundwater contaminants through remediation.

In-situ groundwater bioremediation is a technology that encourages growth and reproduction of indigenous microorganisms to enhance biodegradation of organic constituents in the saturated zone. The microbiological processes are used to degrade or transform contaminants to ultimately less toxic or nontoxic forms. This treatment may be applied to VOCs such as the COCs at LHAAP-67 that exceed their respective MCLs in groundwater. Treatment under anaerobic conditions is often applied to these types of contaminants.

In general, the components of the in-situ bioremediation action include:

- **Performing a treatability study.** A number of environmental conditions can slow or stop the biodegradation process. Therefore, prior to initiation of a bioremediation project, a specific microbial enhancement study and general hydrogeologic investigation would be required for the site. These studies are necessary to identify the types and amounts of substances required to stimulate optimum contaminant degradation and specify geologic and geochemistry information for project design. Some of the parameters that are important to consider include the biodegradability, phase-distribution, leaching potential, and chemical reactivity of the contaminants; the mix of contaminants in the plume; soil type and properties; pH; salinity; competing electron acceptors (e.g., sulfates, nitrates); the presence of adequate microbial populations; the presence of adequate microbial populations; and the presence or absence of inhibitory substances.

- **Injecting nutrients into the subsurface at a predetermined location.** Bacteria present in the groundwater can use chlorinated solvents as electron acceptors. Electron donors may include a wide variety of nutrients: sugars (molasses), alcohols (methanol, ethanol), volatile acids (acetate, lactate), and/or wastes (food processing, manure). The COCs at LHAAP-67 can degrade under anaerobic conditions, but microorganisms, mechanisms, and redox requirements differ. Based on results of a treatability study, appropriate nutrients and other materials would be injected into the subsurface. For this FS, it is assumed that a Hydrogen Release Compound® (HRC®), a sticky gel, would best degrade the COCs at LHAAP-67. HRC® is a polyacetate compound especially formulated for the slow release of lactate into water (Regenesis, 2002). The HRC® compound is typically heated to reduce its viscosity and injected with a high viscosity fluid pump. In addition to the application of HRC®, degradation of the 1,1-dichloroethene to vinyl chloride may require additional materials, such as KB-1 (Cox, 2002). The plume would be gridded with direct-push technology injection sites through which the various materials would be injected. The injection grid would be set up with 1,026 injection points to cover the entire groundwater plume. It is anticipated that the material would be injected once and that the injection would occur in the shallow zone, 15 feet bgs.

- **Sampling wells to monitor effectiveness.** Monitoring for contaminants would be performed to assess the effectiveness of the treatment. Anticipated remediation times may be short with appropriate contact. Assuming first order anaerobic degradation rates and reasonable half-lives for the COCs, the COCs could be reduced to their respective MCLs in approximately 2 years. Additional monitoring is recommended for one to three years after reduction of the COCs to the MCLs. Since there is considerable uncertainty about achieving sufficient contact between the contaminated groundwater and the injected material, the groundwater would continue to be monitored for the maximum recommended period, three years, after reduction of the COCs to the MCLs.

More extensive environmental monitoring would be performed under this alternative than for Alternative 2. A more extensive groundwater monitoring network would be established with the installation of five new monitoring wells in addition to the seven existing monitoring wells located at LHAAP-67. The frequency of sampling would be greater so that trends of contaminant concentrations could be identified. Additional analytes would be collected to assess the biological condition of the groundwater. Groundwater would also be monitored to verify that the COCs in groundwater do not migrate to Central Creek at such levels that ARARs are exceeded. After the treatability and pilot studies have been completed, groundwater sampling would occur five times for the first year, quarterly for year two, and semi-annually for years three through five. Should sampling results show unusual trends or perturbations, additional investigative sampling would be performed. The treatment method may require modification if concentrations do not decrease as anticipated.

5.2.4 Alternative 4 – Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (short term)

The goals of this alternative are similar to those of Alternative 3: to achieve MCLs for the COCs throughout the groundwater contaminant plume at LHAAP-67 and to prevent human exposure to groundwater contamination until the MCLs are achieved throughout the plume. To achieve these goals, this alternative uses groundwater extraction to restore the groundwater to MCLs and maintains land use controls only until such time that the MCLs are achieved for groundwater contaminants through remediation. The extracted groundwater would be piped to the existing groundwater treatment plant.

Groundwater remediation component of this alternative would involve the extraction of contaminated groundwater by means of recovery wells or interception trenches (provided the results of the predesign studies warrant their use) and treatment of the extracted water at the existing groundwater treatment plant located approximately 6,500 feet directly southwest of LHAAP-67 on the southwest side of Harrison Bayou. The purpose of this “pump and treat” system would be to meet MCLs throughout the groundwater contaminant plume. Groundwater contamination at LHAAP-67 exists primarily in the form of VOCs and is currently found in the shallow groundwater zone.

This action would begin with a pre-design study. The study would identify the latest areas of contamination through several rounds of sampling. A pump test would likely be conducted to assess aquifer conditions. Other hydrogeologic parameters would be collected to better design the system. During the design activities, extraction trenches would also be evaluated. A groundwater fate and transport model would be developed to assess the likely time required for remediation and to set performance evaluation parameters.

There are a multiple existing shallow monitoring wells at LHAAP-67 that can be converted to extraction wells. Most of these monitoring wells are 4-inch-diameter, stainless steel wells, 16 feet or less in depth, with screen lengths of 10 feet that penetrate the entire thickness of the geologic unit containing the shallow groundwater zone. It is assumed that 2 existing shallow monitoring wells would be converted to extraction wells and 9 additional extraction wells would be installed for a total of 11 wells. These 11 wells would be used to extract groundwater from the groundwater plume at LHAAP-67. The anticipated average yield from these wells is a total of 11 gallons per minute. For costing purposes, 9,600 linear feet of 4-inch HDPE pipe was assumed to be needed to bring the water from each well to the treatment plant. Backflow preventer valves would be installed on each run of pipe. Air release valves would be installed at four topographic high points. The length of pipeline would require one booster pump and nine clean outs to facilitate cleaning of the line. The HDPE pipes would be installed to depth of 3 feet in a sandy granular material. The valves and pumps would be installed in concrete vaults. These estimates are for costing purposes only and will likely be modified during the design.

5.2.4.1 Water Treatment

The extracted groundwater from LHAAP-67 would be treated at the groundwater treatment plant. The treatment plant was originally built to treat water containing VOCs and metals from extracted groundwater at other LHAAP sites using air stripping, carbon adsorption, and thermal oxidation. Perchlorate treatment using a fluidized bed reactor was added in April 2001. **Figure 5-1** shows a simplified flow diagram of the primary treatment components in the existing plant.

Under Alternative 4, all ex-situ groundwater treatment would be through the groundwater treatment plant. Plant influent from the groundwater extraction system installed at LHAAP-67 under this alternative and the existing groundwater extraction systems at other LHAAP sites

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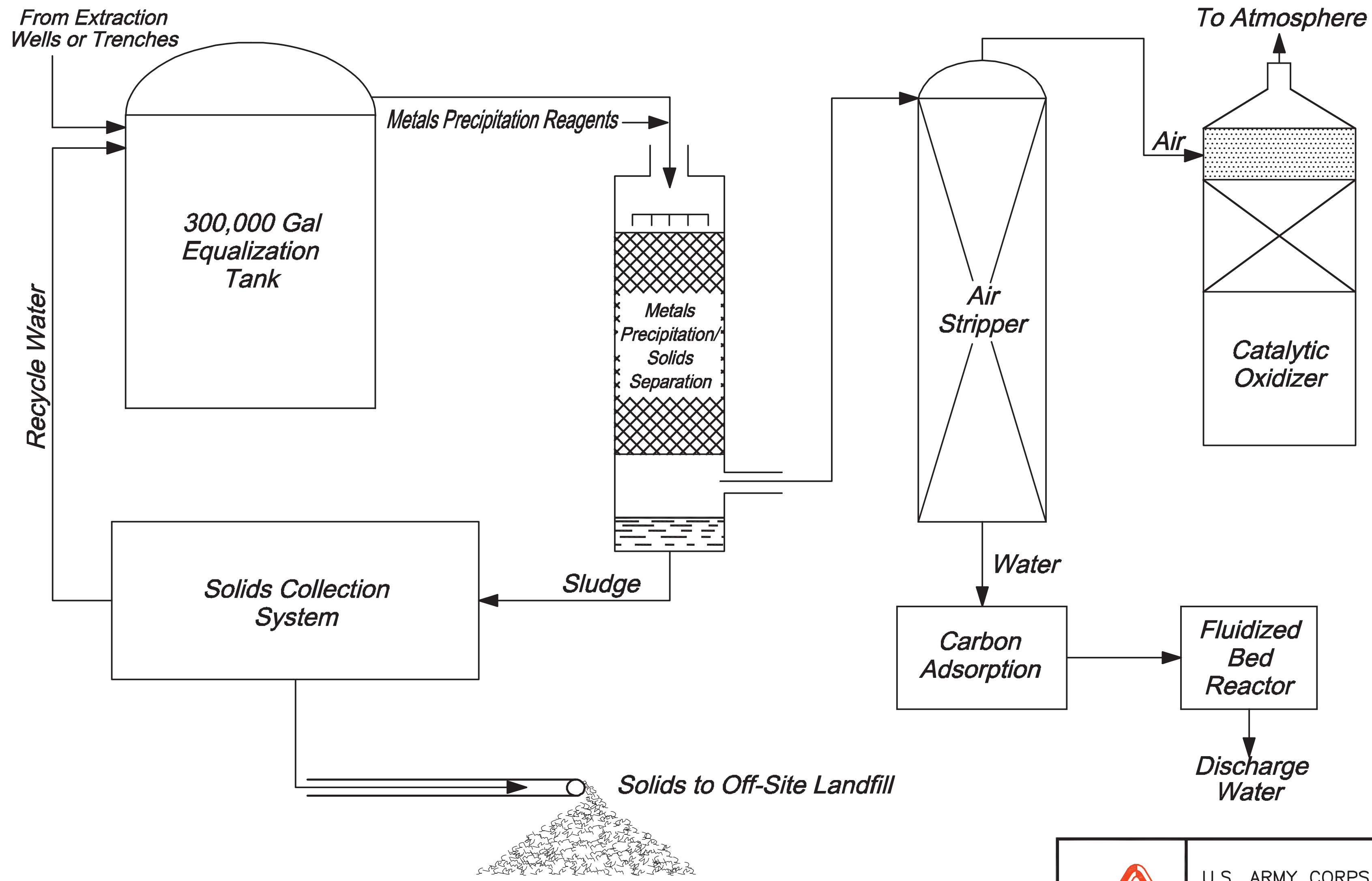

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FIGURE 5–1
EXISTING GROUNDWATER TREATMENT
PLANT PROCESS
FEASIBILITY STUDY, LHAAP–67, GROUP 4
LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

would be blended in the existing 300,000-gallon equalization tank before treatment. Treated effluent would be discharged into Harrison Bayou.

The treatment plant, presently operating at a fraction of its maximum capacity, treats 1 to 1.5 million gallons of extraction water per month from other LHAAP sites. For Alternative 4, a composite average volume of 11 gallons per minute of contaminated water from all of the extraction wells would be treated. The original plant components have adequate capacity to accommodate the increase in influent flow rate.

5.2.4.2 *Long-Term Operation*

Groundwater extraction wells would require regular maintenance to prevent fouling of well screens, and the extraction pumps would also ultimately require replacement. Cleaning of the pipelines, refurbishing pumps, and other maintenance activities would be needed on the groundwater collection and transport system. The groundwater treatment plant has significant long-term O&M requirements, including addition of chemicals, power, and labor; equipment cleaning, maintenance, and replacement; and regulatory monitoring and reporting.

More extensive environmental monitoring would be performed under this alternative than for Alternative 2. A more extensive groundwater monitoring network would be established with the installation of five new monitoring wells in addition to the five existing monitoring wells located at LHAAP-67. The frequency of sampling would match that of Alternative 2. Groundwater would be monitored to ensure that the COCs in groundwater do not migrate to Central Creek at such levels that ARARs are exceeded. Monitoring would continue as required to demonstrate compliance with ARARs and the RAO and in support of the 5-year reviews required by CERCLA Section 121 (c). If sampling results showed unusual trends or perturbations, additional investigative sampling would be performed. If the extraction system is determined to be ineffective, modifications to the system may be required.

5.3 *Action-Specific ARARs*

5.3.1 *Introduction*

Action-specific ARARs include operation, performance, and design requirements or limitations based on the waste types, media, and remedial activities. This section provides a preliminary identification and evaluation of potential federal and state of Texas action-specific ARARs for the proposed alternatives for remediation of LHAAP-67. For a discussion of definitions and methods used to analyze ARARs, see **Section 3.2.1**.

Three alternatives, other than a baseline no action alternative, have been proposed for the remediation of LHAAP-67. All of the alternatives are described in detail in **Section 5.2**. Pursuant to USEPA guidance, there are no action-specific ARARs for the no action alternative (USEPA, 1991). ARARs for the activities common to all three action alternatives are discussed in **Section 5.3.2** below. All action-specific ARARs are listed in **Table 5-1** and are grouped by component action. The "Prerequisite" column in **Table 5-1** indicates which alternatives include that component action.

5.3.2 ARARS for Activities Associated with Action Alternatives

All of the alternatives other than the no action alternative involve one or more of the following activities: waste generation, characterization, management, storage, and disposal activities; land use controls and long-term monitoring; well construction; and water treatment. Action-specific ARARs are discussed here for the activities common to the remedial alternatives proposed for LHAAP-67.

5.3.2.1 Waste Generation, Characterization, Management, Storage, and Disposal Activities

The processes of monitoring, intercepting, or treating contaminated groundwater may generate a variety of primary and secondary waste streams (e.g., soil, personal protective equipment, dewatering and decontamination fluids). These waste streams are expected to be non-hazardous waste. All solid waste (defined as any solid, liquid, semisolid, or contained gaseous material intended for discard [40 CFR 261.2]) generated during remedial activities must be appropriately characterized to determine whether it contains Resource Conservation and Recovery Act (RCRA) hazardous waste (40 CFR 262.11; 30 TAC 335.62; 30 TAC 335.503[a][4]; 30 TAC 335.504). All wastes must be managed, stored, treated (if necessary), and disposed of in accordance with the ARARs for waste management listed in **Table 5-1** for the particular type of waste stream or contaminants in the waste.

Excavated environmental media including soil excavated during the installation of monitoring/extraction wells would be sent off site for disposal or, in the case of non-hazardous trenching or well construction soil, redeposited within the area of contamination (AOC). USEPA defines "onsite" as the areal extent of contamination and all suitable areas in close proximity to the contamination necessary for the implementation of the CERCLA response action and notes that such contamination may contain varying types and concentrations of hazardous substances (53 FR 51444; 55 FR 8758). The soil generated from remedial activities at LHAAP-67 is expected to be nonhazardous. ARARs for the management of such media at the site of generation (i.e., within the AOC) are listed in **Table 5-1**.

The USEPA has stated that excavation and redeposition of contaminated soil within an AOC does not constitute "generation"; therefore, the requirements of 40 CFR 262.11 and 268.7 to

Table 5-1
Action-Specific ARARs for Remedial Alternatives

Citation	Activity or Prerequisite/Status	Requirement
Waste Generation, Management, and Storage		
Characterization of Solid Waste 40 CFR 262.11 30 TAC 335.62 30 TAC 335.504 30 TAC 335.503(a)(4)	Generation of solid waste, as defined in 30 TAC 335.1**—applicable** (Alternatives 2, 3 and 4)	Must determine whether the generated solid waste is RCRA hazardous waste by using prescribed testing methods or applying generator knowledge based on information regarding material or process used. If the waste is determined to be hazardous, it must be managed in accordance with 40 CFR 262–268. After making the hazardous waste determination as required, if the waste is determined to be nonhazardous, the generator shall then classify the waste as Class 1, Class 2, or Class 3 (as defined in Section 335.505 through Section 335.507) using one or more of the methods listed in Section 335.503(a)(4) and Section 335.508 and manage the waste in accordance with the requirements of Chapter 335 of the TAC for industrial solid waste.
Characterization of Hazardous Waste 40 CFR 264.13(a)(1); 40 CFR 268.7 30 TAC 335.504(3) 30 TAC 335.509 30 TAC 335.511	Generation of a RCRA hazardous waste for treatment, storage, or disposal**—applicable** if hazardous waste is generated (e.g., PPE) (Alternatives 2, 3 and 4)	Must obtain a detailed chemical and physical analysis of a representative sample of the waste(s) that at a minimum contains all the information that must be known to treat, store, or dispose of the waste in accordance with 40 CFR 264 and 268. Must also determine whether the waste is restricted from land disposal under 40 CFR 268 et seq. by testing in accordance with prescribed methods or use of generator knowledge of waste.
Management of RCRA Hazardous Waters—Wastewater Treatment Unit Exclusion 40 CFR 264.1(g)(6) 40 CFR 270.1(c)(2) 30 TAC 335.41(d)(1)	Treatment/disposal of wastewater containing RCRA hazardous waste**—applicable** to management of contaminated groundwater if it is determined to contain RCRA characteristically hazardous waste (Alternative 2, 3 and 4)	On-site wastewater treatment units, as defined in 40 CFR 260.10, that are part of a wastewater treatment facility subject to regulation under Section 402 or Section 307(b) of the CWA are excluded from the requirements of RCRA Subtitle C (Note: USEPA has clarified that this exemption applies to all tank systems, conveyance systems, and ancillary equipment, including transfer trucks, associated with the wastewater treatment unit [53 FR 34079, September 2, 1988]).
Requirements for Temporary Storage of Hazardous Waste in Accumulation Areas 40 CFR 262.34(a) and (c)(1) 30 TAC 335.69(a) and (d)	On-site accumulation of 55 gallons or less of RCRA hazardous waste for 90 days or less at or near the point of generation**—applicable** if hazardous waste is generated (e.g., PPE) and stored in an accumulation area (Alternatives 2, 3 and 4)	A generator may accumulate hazardous waste at the facility provided that • Waste is placed in containers that comply with 40 CFR 264.171 to 264.173 (Subpart I); and • Container is marked with the words “hazardous waste”; or • Container may be marked with other words that identify the contents.

Table 5-1 *(continued)*
Action-Specific ARARs for Remedial Alternatives

Citation	Activity or Prerequisite/Status	Requirement
Requirements for the Use and Management of Containers 40 CFR 264.171–264.173 30 TAC 335.69(e) 30 TAC 335.152(a)(7)	On-site storage/treatment of RCRA hazardous waste in containers for greater than 90 days—**applicable** if hazardous waste is generated (e.g., PPE) and is stored in containers (Alternatives 2, 3 and 4)	Design and operating standards of 40 CFR 264.175(c) and 40 CFR 264.171, 264.172, and 264.173(a) and (b) must be met for the use and management of hazardous waste in containers.
Well Construction Standards—Monitoring or Injection Wells 16 TAC 76.1000	Construction of water wells—**applicable** to construction of new monitoring or injection wells, if needed (Alternatives 2, 3 and 4)	Wells shall be completed in accordance with the technical requirements of Section 76.1000, as appropriate.
Well Construction Standards—Extraction Wells 16 TAC 76.1000(a) and (c) through (h) 16 TAC 76.1002(a) through (c) 16 TAC 76.1008(a) through (c)	Construction of water wells—**applicable** to construction of extraction (recovery) wells (Alternative 4)	Wells shall be completed in accordance with the technical requirements of Section 76.1000, as appropriate. Water wells completed to produce undesirable water shall be cased to prevent the mixing of water or constituent zones. The annular space between the casing and the wall of the borehole shall be pressure grouted with cement or bentonite grout to the land surface. Bentonite grout may not be used if a water zone contains chloride water above 1500 ppm or if hydrocarbons are present. Wells producing undesirable water or constituents shall be completed in such a manner that will not allow undesirable fluids to flow onto the land surface. During installation of a water well pump, installer shall make a reasonable effort to maintain integrity of groundwater and to prevent contamination by elevating the pump column and fittings, or by other means suitable under the circumstances. Pump shall be constructed so that no unprotected openings into the interior of the pump or well casing exist.

Table 5-1 *(continued)*
Action-Specific ARARs for Remedial Alternatives

Citation	Activity or Prerequisite/Status	Requirement
Treatment/Disposal		
Disposal of Wastewater (e.g., contaminated groundwater, dewatering fluids, decontamination liquids) 40 CFR 268.1(c)(4)(i) 30 TAC 335.431(c)	RCRA-restricted characteristically hazardous waste intended for disposal**—applicable** if extracted groundwater is determined to be RCRA characteristically hazardous (Alternatives 2, 3 and 4)	Disposal is not prohibited if such wastes are managed in a treatment system subject to regulation under Section 402 of the CWA that subsequently discharges to waters of the United States.
Closure		
Requirements for Closure of a RCRA Container Storage Area 40 CFR 264.111 40 CFR 264.178 30 TAC 335.152(a)(5) 30 TAC 335.152(a)(7)	Closure of a RCRA-permitted container storage area**—applicable** if hazardous waste is generated (e.g., PPE) and is stored in containers (Alternatives 2, 3 and 4)	Must close unit in a manner that • Minimizes the need for further maintenance; • Controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to ground or surface waters or to the atmosphere; and • Complies with closure requirements of 40 CFR 178. All hazardous waste and residues must be removed from containment system. Remaining containers, liners, bases, and soil containing or contaminated with hazardous waste or residues must be decontaminated or removed.
Standards for Plugging Wells that Penetrate Undesirable Water or Constituent Zones 16 TAC 76.1004(a) through (c)	Plugging and abandonment of wells**—applicable** to plugging and closure of monitoring and/or extraction wells (Alternatives 2, 3 and 4)	If a well is abandoned, all removable casing shall be removed and the entire well pressure filled via a tremie pipe with cement from bottom up to the land surface. In lieu of this procedure, the well shall be pressure-filled via a tremie tube with bentonite grout of a minimum 9.1 lb/gal weight followed by a cement plug extending from land surface to a depth of not less than 2 feet. Undesirable water or constituents or the freshwater zone(s) shall be isolated with cement plugs.
Post-Closure Care and Land Use Controls		
Warning Signs in Contaminated Areas 30 TAC 335.443-448	Hazardous substances left in place on contaminated property**—relevant and appropriate** (Alternatives 2, 3 and 4)	Placement of warning signs on property contaminated with hazardous substances is required when such contamination presents a danger to public health or safety. Warning signs can be removed when it is determined that the remedial action on the contaminated property is complete and that no further hazard to the public health and safety exists.

Table 5-1 *(continued)*
Action-Specific ARARs for Remedial Alternatives

Citation	Activity or Prerequisite/Status	Requirement
Land Use Controls and Deed Recordation when Hazardous Substances are Left in Place 30 TAC 335.565 30 TAC 335.566	Hazardous substances left in place on contaminated property—**relevant and appropriate** (Alternatives 2, 3 and 4)	Where engineering or land use control measures are required to protect human health and the environment, they must comply with the identified post-closure care requirements and deed recordation of the facility in accordance with Section 335.566. Must record in the deed records of the county or counties in which the activities take place the information specified in Sections 335.566(b) through (e): • Description of post-closure measures required, • Description of any land use or legal controls placed on the future use of the property, • Metes and bounds description of the tract of land, and • Statement that pertinent information and documents are available for inspection.

Abbreviations:

ARAR	*applicable or relevant and appropriate requirement*
CFR	*Code of Federal Regulations*
CWA	*Clean Water Act of 1972*
USEPA	*U.S. Environmental Protection Agency*
FR	*Federal Register*
FS	*feasibility study*
lb/gal	*pound per gallon*
LHAAP	*Longhorn Army Ammunition Plant*
%	*percent*
PPE	*personal protective equipment*
ppm	*part per million*
RCRA	*Resource Conservation and Recovery Act of 1976*
TAC	*Texas Administrative Code*

characterize generated wastes are not applicable (Office of Solid Waste and Emergency Response Directive 9441.1992[16], June 11, 1992). Consolidation of waste between AOCs for treatment or disposal, however, or excavation and treatment with subsequent disposal in the same AOC or off-site disposal constitute "placement." In these situations, RCRA Subtitle C requirements for the generation, handling, treatment, and disposal of such wastes are applicable if the waste/media is determined to contain RCRA hazardous waste (55 FR 8758) (USEPA, 1989b).

5.3.2.2 Land Use Controls and Long-Term Monitoring

Some combination of deed restrictions (if property becomes owned by a non-government entity), restrictive covenants, administrative controls, physical barriers, physical surveillance or other controls, in combination with long-term monitoring of groundwater, would be necessary under all active alternatives to restrict access to contamination and protect human health and the environment because none of the alternatives completely removes all of the groundwater contamination to levels that would allow unrestricted access and use of the groundwater in the near term. Alternatives 3 and 4, however, may reduce such contamination in groundwater to unrestricted access levels in the future.

When engineering or land use control measures are required to protect human health and the environment, 30 TAC 335.565 requires compliance with the identified post-closure care requirements and deed recordation of the facility in accordance with Sections 335.566(b) through (e). The deed recordation must include a description of post-closure measures required and any land use controls placed on the future use of the property, as well as a metes and bounds description of the tract of land. Some or all of these requirements may be ARARs for this remedial action; the specific combination of controls negotiated for this action would be listed in a signed ROD.

Texas has also promulgated standards in 30 TAC 335, Subchapter P, for the placement of warning signs on property contaminated with hazardous substances when such contamination presents a danger to public health or safety. Warning signs can be removed when it is determined that the remedial action on the contaminated property is complete and no further hazard to the public health and safety exists.

5.3.2.3 Well Construction

All of the alternatives involve the placement, use, or eventual plugging and abandonment of some type of groundwater monitoring, injection, and/or extraction wells, either for in-situ treatment or extraction of the contaminated groundwater or for long-term monitoring of the groundwater. Available standards for well construction and plugging/abandonment would provide ARARs for such actions.

Texas has promulgated technical requirements in Chapter 76 of Title 16 of the TAC applicable to construction, operation, and plugging/abandonment of water wells. In particular, 16 TAC 76.1000 (*Locations and Standards of Completion for Wells*), 16 TAC 76.1002 (*Standards for Wells Producing Undesirable Water or Constituents*) (LHAAP-67 contaminated groundwater could be considered "undesirable water" defined pursuant to Section 76.10[36] as "water that is injurious to human health and the environment or water that can cause pollution to land or other waters"), 16 TAC 76.1004 (*Standards for Capping and Plugging of Wells and Plugging Wells that Penetrate Undesirable Water or Constituent Zones*), and 16 TAC 76.1008 (*Pump Installation*) may provide ARARs for the placement, construction, and eventual plugging/abandonment of groundwater injection or extraction wells under Alternatives 3 and 4 or the placement and long-term operation of groundwater monitoring wells under all alternatives.

5.3.2.4 Water Treatment

Contaminated groundwater and wastewaters collected during well drilling or decontamination activities could be transported to the on-site water treatment facility constructed as a component of the previous interim remedial action at other LHAAP sites and would subsequently be discharged in compliance with the CWA outfall limits for the facility as listed in the ROD. Such waters would be characterized, as required, before transport and managed accordingly in compliance with requirements for the type of waste contaminating the water.

The USEPA has stated, however, that any waters that are hazardous only because they exhibit a hazardous characteristic, and which are otherwise restricted from land disposal, are not prohibited if such waters are managed in a treatment system that subsequently discharges to waters of the United States pursuant to Section 402 of the CWA (40 CFR 268.1[c][4][I]). To assure compliance with the water treatment plant's discharge limits, the incoming water must meet the waste acceptance criteria for the facility. On-site wastewater treatment units (as defined in 40 CFR 260.10) that are part of a wastewater treatment facility that is subject to regulation under Section 402 or Section 307(b) of the CWA are not subject to RCRA Subtitle C hazardous waste management standards (40 CFR 270.1[c][2][v]; 40 CFR 264.1[g][6]; 30 TAC 335.42[d][1]). USEPA has clarified that this exemption applies to all tanks, conveyance systems, and ancillary equipment, including piping and transfer trucks, associated with the wastewater treatment unit (53 FR 34079, September 2, 1988).

6.0 Detailed Analysis of Alternatives

6.1 Introduction

The detailed analysis of alternatives presents and assesses relevant information that provides the basis for selecting an alternative and preparing a ROD. **Section 6.2** provides an overview of the evaluation criteria. The detailed analysis begins with an individual analysis in **Section 6.3** in which each alternative is individually evaluated according to the evaluation criteria identified in the NCP (40 CFR 300.430). Following the individual analysis, the alternatives are compared in relation to the two threshold criteria and then the alternatives are assessed regarding the five balancing criteria, highlighting the key advantages, disadvantages, and trade-offs that are considered as part of the evaluation process.

6.2 Overview of the Evaluation Criteria

CERCLA, Section 121, as amended, specifies statutory requirements for remedial actions. These requirements include protection of human health and the environment, compliance with ARARs, a preference for permanent solutions that incorporate treatment as a principal element to the maximum extent practicable, and cost-effectiveness. To assess whether alternatives meet the requirements, the USEPA has identified nine criteria in the NCP (40 CFR 300.430) that must be evaluated for each alternative considered for selection (Section 300.430[e][9][iii]). Provided here are summaries of the factors that comprise the nine criteria and an overview of the approach taken by this FS to address these criteria.

6.2.1 Criterion 1: Overall Protection of Human Health and the Environment

This evaluation criterion assesses whether the alternative achieves and maintains adequate protection of human health and the environment in accordance with the RAO established in **Section 3.0**. Because the scope of this criterion is broad, it also reflects the discussions of the subsequent criteria, including long-term effectiveness and permanence, and short-term effectiveness. Evaluation of this criterion describes how site risks associated with each pathway are eliminated, reduced, or mitigated through treatment, engineering, or land use controls. This criterion also considers whether an alternative poses an unacceptable short-term or cross-media affect.

6.2.2 Criterion 2: Compliance with ARARs

This criterion addresses compliance with promulgated federal and state environmental requirements. The detailed analysis summarizes which requirements are applicable or relevant and appropriate to an alternative and how the alternative meets these requirements. If an alternative cannot meet a requirement, a determination can be made that a waiver under CERCLA may be appropriate, and a basis for justifying the waiver is presented. ARARs consist of two sets of requirements – those that apply and those that are relevant and appropriate. In certain cases, standards may not exist that address the proposed action or the COC(s). In such cases, nonpromulgated advisories, criteria, or guidance developed by the USEPA or other federal agencies or states can be TBCs. There are three types of ARARs; chemical-specific, location-specific, and action-specific. The chemical- and location-specific ARARs are presented in **Section 3.2**. **Section 5.3** presents action-specific ARARs for the developed alternatives.

6.2.3 Criterion 3: Long-Term Effectiveness and Permanence

This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the RAO is met. The criterion considers the degree to which the alternative provides sufficient long-term controls and reliability to prevent exposures that exceed protective levels for human and environmental receptors. The principal factors addressed by this criterion include magnitude of residual risk and the adequacy and reliability of controls to address such risk. This criterion also addresses the uncertainties associated with these factors.

The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, containment, or institutional measures that are part of the alternative. Factors considered include performance characteristics, maintenance requirements, and expected durability. Information and data from past performance and similar technology applications are incorporated appropriately into the evaluation. Land use controls are considered where they have the potential to improve the effectiveness of engineered measures.

6.2.4 Criterion 4: Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion reflects the statutory preference that remedial alternatives contain a principal component that substantially reduces toxicity, mobility, or volume of hazardous substances through treatment. The evaluation regarding this criterion considers the extent to which alternative technologies can effectively and permanently fix, transform, immobilize, or reduce the volume of waste materials and contaminated media.

6.2.5 Criterion 5: Short-Term Effectiveness

This criterion addresses the effects of the construction and implementation phases of the alternative until the RAO is achieved. The evaluation regarding this criterion considers the effect on human health and the environment posed by operations conducted during the remedial action phases. Both the potential effect and associated mitigative measures are examined for maintaining protectiveness for the community, remediation workers, and environmental receptors throughout the duration of activities.

Potential short-term risks to the pubic include inhalation of constituents that may be released during waste removal and treatment operations, and contaminant exposure and physical injury during waste transport off site. Potential short-term risks to workers include direct contact and exposure during construction, waste handling, and transportation; physical injury or death during construction and transportation activities; and nonremediation worker exposures to airborne contaminants during waste and soil removal operations. Alternative analyses also include a description of mitigating measures such as engineering and land use controls that are expected to minimize potential risks to the public and workers. This evaluation also addresses the anticipated duration of remedial activities.

6.2.6 Criterion 6: Implementability

This criterion examines the technical and administrative factors affecting implementation of an alternative and considers the availability of services and materials required during implementation. Technical factors to be assessed include the ease and reliability of construction and operations, the prospects for implementing a future action, and the adequacy of monitoring systems to detect failures. Administrative factors include permitting and coordination requirements between the lead agency and regulatory agencies. Service and material considerations include TSD capacities, equipment and operator availability, and prospective technology applicability or development requirements.

The assessment of technical feasibility examines the performance history of the technologies in direct applications or considers the expected performance for similar applications. Uncertainties associated with construction, operation, and performance monitoring are also addressed.

The evaluation of administrative feasibility includes a discussion of those actions required to coordinate with regulatory agencies to establish the framework for complying with key substantive technical requirements that must be met by an alternative. Additionally, those alternatives that include off-site transportation of waste are reviewed to assess the feasibility of off-site disposal.

The availability of services and materials is addressed by analyzing the material components of the proposed technologies to determine the locations and quantities of those materials, and by reviewing process operations to identify special services, operator skills, or training required to readily implement the process.

The NCP requires that the evaluation of the relative administrative feasibility of each alternative include "…activities needed to coordinate with other offices and agencies, and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions). CERCLA, Section 121(e), stipulates that no deferral, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site." An action must satisfy the substantive requirements of the permits that will otherwise be required.

6.2.7 Criterion 7: Cost

Cost estimates are included for each remedial alternative. The estimates are based on feasibility level scoping and are intended to aid in making project evaluations and comparisons among alternatives. The estimates have an expected accuracy of +50 to –30 percent for the scope of the action described in **Section 5.0** for each alternative.

The estimates are divided into capital cost and O&M cost, and are developed according to an assumed schedule for the various activities based on similar project experience.

Capital costs are defined as those expenditures required to initiate and install an alternative. These are short-term costs and are exclusive of costs required to maintain the action throughout the project lifetime. Capital costs consist of direct and indirect costs. Direct costs include construction costs (material, labor, and equipment to install an action), service equipment, process and new process buildings, utilities, and waste disposal costs. Indirect costs include design engineering, inspection, project integration, project administration and management, and project contingencies.

O&M costs are long-term costs associated with ongoing remediation at a site. These costs occur after construction and installation are completed. The costs include labor, materials, utilities, and services required to monitor, operate, and maintain the facilities for a period of up to 30 years.

The estimated present worth of each remedial alternative is determined on a discount rate of 7 percent and a base maintenance/monitoring period of up to 30 years.

Appendix A presents detailed cost estimates and the major assumptions used to develop the cost estimates for each remedial alternative.

6.2.8 Criterion 8: State Acceptance

State acceptance of an alternative will be evaluated in the proposed plan issued for public comment. Therefore, this criterion is not considered in this FS.

6.2.9 Criterion 9: Community Acceptance

Community acceptance of each alternative will be evaluated after a proposed plan is issued for public comment. Therefore, this criterion is not considered in this FS.

6.3 Individual Analysis of Alternatives

6.3.1 Alternative 1 – No Action

Under the no action alternative, no further action would be taken to control human exposure to contaminated groundwater or to monitor potential groundwater impacts to surface water. The contaminated groundwater would remain in place without the implementation of any contaminant removal, treatment, or containment. Land use controls to prevent access to contaminated site groundwater would not be implemented. This alternative provides a baseline for comparison purposes.

6.3.1.1 Overall Protection of Human Health and the Environment

The no action alternative does not achieve the RAO for LHAAP-67. This alternative provides no control of exposure to the contaminated groundwater and no reduction in the risks to human receptors for current and future land use scenarios. Risks to receptors from ingestion of groundwater contaminants would exceed the USEPA-established threshold for acceptable incremental lifetime cancer risk of 1×10^{-4} for carcinogens or an HI of 1 for noncarcinogens. Furthermore, this alternative does not address the potential impact of groundwater contaminants on Central Creek.

6.3.1.2 Compliance with ARARs

CERCLA, Section 121, cleanup standards, including compliance with ARARs, apply only to actions the USEPA determines should be taken under CERCLA, Sections 104 and 106 authority. A no action decision will be made when no action is deemed necessary to reduce, control, or mitigate exposure because the site does not present a threat to human health and the environment, or because any action taken will worsen the negative effects on human health and the environment. Because no remedial activities are associated with this alternative, compliance with chemical-specific ARARs would not be met. Since no remedial activities would be conducted, action-specific and location-specific ARARs would not apply.

6.3.1.3 Long-Term Effectiveness and Permanence

6.3.1.3.1 Magnitude of Residual Risk

The no action alternative would not provide a long-term solution that is effective or permanent. The residual risk and toxicity from groundwater exposure under a no action alternative would be unacceptable at LHAAP-67. The carcinogenic risk exceeds 1×10^{-3} and the toxicity is above acceptable levels. Most of the risk is due to 1,1-DCE. These risks were calculated for a future maintenance worker ingesting the groundwater, although this scenario is unlikely. Currently, the groundwater at LHAAP-67 is not used for drinking water, and would not be used for drinking water under a wildlife refuge future use scenario. The groundwater COCs could also potentially migrate toward and impact Central Creek, which flows to Caddo Lake, a drinking water supply. However, the results of plume migration modeling indicate that the maximum concentrations of the COCs within Central Creek after plume impact would be below groundwater and surface water ARARs, which also would be protective of Caddo Lake.

6.3.1.3.2 Adequacy and Reliability of Controls

The no action alternative would not provide the maintenance of land use controls at LHAAP-67 and, therefore, would not reduce the existing exposure risks posed by contaminated site groundwater.

6.3.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Implementation of the no action alternative would not reduce toxicity, mobility, or volume of contaminants because this alternative does not employ treatment.

6.3.1.5 Short-Term Effectiveness

Under the no action alternative, no remedial action would be taken; therefore, the short-term effectiveness criterion is not applicable to this alternative. No short-term risks to workers, the community or the environment would exist.

6.3.1.6 Implementability

This alternative is inherently implementable because no remedial action would be taken..

6.3.1.7 Cost

There are no costs associated with the no action alternative.

6.3.2 Alternative 2 – Land Use Controls

Alternative 2 includes the maintenance of land use controls to prevent human exposure to contaminated groundwater at LHAAP-67. Land use controls are a major portion of the alternative as the groundwater contamination presenting an unacceptable risk to human health would remain untreated. Monitoring activities associated with the land use controls would ensure that the COCs in groundwater do not discharge to surface water in Central Creek at such levels that ARARs are exceeded.

6.3.2.1 Overall Protection of Human Health and the Environment

6.3.2.1.1 Protection of Human Health

This alternative would achieve the RAO for LHAAP-67. Continued maintenance of the land use controls would prevent human access and exposure to groundwater that poses an unacceptable risk to human health. The controls would include a combination of Army procedures, training, and/or posting of signs. Deed restrictions would be placed on the property to prohibit or restrict property uses (e.g., drinking water well installation) that may result in exposure to groundwater. The groundwater monitoring activities associated with land use controls would monitor groundwater plume migration and ensure that the COCs in groundwater do not discharge to surface water at levels that would be detrimental to Central Creek and Caddo Lake (a drinking water supply).

6.3.2.1.2 *Protection of the Environment*

A site-wide ecological baseline risk assessment is in the process of being performed for the Group 4 sites; therefore, it is unknown what, if any, environmental receptors are at risk from exposure to the contaminants at LHAAP-67. The results of the pending site-wide ecological risk assessment may indicate that additional action is necessary based on ecological risk.

6.3.2.2 *Compliance with ARARs*

6.3.2.2.1 *Chemical-Specific ARARs*

This alternative would not achieve the chemical-specific ARARs for contaminants that exceed their respective MCLs in groundwater. However, this alternative would verify through monitoring activities that COCs in groundwater do not impact surface water bodies such that ARARs are exceeded.

6.3.2.2.2 *Location-Specific ARARs*

The activities that would be conducted under this alternative would comply with all location-specific ARARs. No activities would take place in sensitive environments such as wetlands, and no impacts to archeological resources are anticipated. Due to the limited number and locations of the activities associated with this alternative, threatened and endangered species would not likely be impacted.

6.3.2.2.3 *Action-Specific ARARs*

The activities that would be conducted under this alternative would comply with all action-specific ARARs.

6.3.2.3 *Long-Term Effectiveness and Permanence*

6.3.2.3.1 *Magnitude of Residual Risks*

The implementation of land use controls under this alternative would prevent direct contact by human receptors with the groundwater at LHAAP-67, thus minimizing the potential risk posed by groundwater contamination. The risk from ingestion of the groundwater is primarily from 1,1-DCE. The groundwater COCs could also potentially migrate toward and impact Central Creek, which flows to Caddo Lake, a drinking water supply. However, the results of plume migration modeling indicate that the maximum concentrations of the COCs within Central Creek after plume impact are below groundwater and surface water ARARs, which also would be protective of Caddo Lake.

6.3.2.3.2 *Adequacy and Reliability of Controls*

The implementation of land use controls would protect potential human receptors from exposure to contaminated groundwater at LHAAP-67 and would ensure continued compliance with risk-reduction goals at the various potential points of exposure. The reliability of land use controls would depend on the long-term maintenance of the controls. Maintenance of the land use controls and environmental monitoring associated with these controls would be required indefinitely since groundwater COC concentrations would remain on site above their respective MCLs over the long term. The effectiveness of the land use controls would depend on the annual and five-year CERCLA reviews and inspections of any physical mechanisms in place at LHAAP-67. The 5-year reviews may indicate the need for components of this alternative to be maintained, modified, or replaced.

6.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would not reduce the toxicity, mobility, or volume of COCs in groundwater through an active remedial process. A reduction in groundwater contaminant concentrations may occur over time through natural processes; however, this reduction is anticipated to be minimal. Although the migration of the groundwater contaminants would be monitored for the duration of the land use controls, no active reduction of contaminant mobility in the groundwater would be accomplished through this alternative.

6.3.2.5 Short-Term Effectiveness

6.3.2.5.1 Protection of the Community During Remedial Action

This alternative is protective of the surrounding community during remedy implementation primarily because all activities would occur on site with very little disturbance of contaminated material.

6.3.2.5.2 Protection of Workers During Remedial Action

No significant short-term risks to human health or the environment would exist during implementation of this alternative. However, worker exposure to contaminated groundwater is possible during sampling activities associated with the monitoring events. The short-term risks associated with groundwater monitoring activities and may be minimized through implementation of an effective health and safety program.

6.3.2.5.3 Short-Term Environmental Effects

Since minimal disturbance of contaminated material would occur under this alternative, short-term impacts to the environment are unlikely. The implementation of proper engineering controls would minimize the risk of environmental impacts.

6.3.2.5.4 Duration of Remedial Activities

Implementation of land use controls would prevent exposure to contaminated groundwater by prohibiting the installation of potable water wells at LHAAP-67. This alternative could provide almost immediate protection because land use controls can be implemented relatively quickly (e.g., within six months). Maintenance of the controls would be required indefinitely since a significant decrease in groundwater contaminant concentrations is not expected over the long term.

6.3.2.6 Implementability

6.3.2.6.1 Technical Feasibility

All components of this alternative are readily implementable. Minimal technical concerns exist that would hinder the implementation of this alternative because no remedial activities would be performed under this alternative. However, maintenance of the land use controls would be required. All equipment, services and materials are readily available to conduct the activities for this alternative.

6.3.2.6.2 Administrative Feasibility

All actions under this alternative are implemented on site and thus do not require permits, though substantive provisions of permits that would otherwise be required are considered to be ARARs. By legal agreement (i.e., the FFA), the USEPA reviews and signs the ROD with TNRCC approval, thereby agreeing to the ARARs. By addressing the identified ARARs in the ROD, it is anticipated that the alternative would adequately address all administrative barriers.

Land use controls, although administratively implementable, would require the following: development of an implementation plan; a site approval process to approve land-use changes to ensure the integrity of the controls; the installation of markers to identify areas of restricted use; training of appropriate personnel regarding the location and care of the controls; and internal notices to relevant regulatory offices of the existence of the land use controls. Approval by the USEPA and the State of Texas is required prior to the modification or termination of land use controls, implementation actions, or modification of land-use by the Army. The Army shall also seek concurrence from the USEPA and the State of Texas prior to any action that may disrupt the effectiveness of the land use controls or any action that may alter or negate the need for land use controls.

6.3.2.7 Cost

The total project present worth cost of this alternative is approximately $221,000. The details of the cost estimates for all of the alternatives are presented in **Appendix A**.

6.3.2.7.1 Direct Capital Cost

The total direct capital cost is estimated at $44,000.

6.3.2.7.2 Indirect Capital Cost

No indirect capital costs are required for this alternative.

6.3.2.7.3 O&M Cost

The total O&M cost is estimated at approximately $364,000. The O&M cost includes maintenance of land use controls and long-term monitoring through year 30. The long-term monitoring would support the required CERCLA 5-year reviews.

6.3.3 Alternative 3 – In-situ Bioremediation, Land Use Controls

This alternative reduces contamination throughout the groundwater plume via in-situ bioremediation to levels that would allow future unrestricted reuse of the site with no long-term reliance on land use controls. However, land use controls would be a significant component of this alternative in the short term until such time that the groundwater meets unrestricted residential cleanup goals (i.e., MCLs are achieved throughout the site). These actions would reduce COC concentrations in the groundwater to the MCLs throughout the site, provided bioremediation treatability testing results are favorable.

6.3.3.1 Overall Protection of Human Health and the Environment

6.3.3.1.1 Protection of Human Health

The remedial action proposed for this alternative would eventually achieve the destruction of the COCs present in groundwater above remediation levels established for LHAAP-67. Therefore, the residual site risk upon completion of these actions would be within the target risk range for an industrial user. Furthermore, since the MCLs would be achieved for the groundwater COCs, residual contamination after completion of the remedial action would not limit the site's future use and would not require exposure limitations; therefore, the site could support unrestricted reuse and unlimited exposure with no long-term reliance on land use controls. This alternative is protective of human health and achieves the RAO for LHAAP-67.

6.3.3.1.2 Protection of the Environment

A site-wide ecological baseline risk assessment for the Group 4 sites is in progress; therefore, it is unknown what, if any, environmental receptors are at risk from exposure to the contaminants at LHAAP-67. The remedial measures implemented in this alternative, however, may provide certain levels of protection for potential environmental receptors. Restoration of LHAAP-67 groundwater would protect Central Creek from discharges of contaminated groundwater that could affect aquatic organisms.

6.3.3.2 Compliance with ARARs

6.3.3.2.1 Chemical-Specific ARARs

This alternative would comply with chemical-specific ARARs for groundwater throughout the site because the contaminant MCLs would be achieved, and would also protect the nearby surface water bodies from ARAR exceedances.

6.3.3.2.2 Location-Specific ARARs

The activities that would be conducted under this alternative would comply with all location-specific ARARs. No activities would take place in sensitive environments such as wetlands, and no impacts to archeological resources or threatened and endangered species are anticipated.

6.3.3.2.3 Action-Specific ARARs

The activities that would be conducted under this alternative would comply with all action-specific ARARs.

6.3.3.3 Long-Term Effectiveness and Permanence

6.3.3.3.1 Magnitude of Residual Risks

Upon completion of groundwater remediation, the residual site risk would be within the target risk range for an industrial user. Furthermore, since the MCLs would be achieved for groundwater COCs, residual contamination after completion of the remedial action would not limit the site's future use and would not require exposure limitations; therefore, the site could support unrestricted reuse and unlimited exposure with no long-term reliance on land use controls. Until the remediation levels are achieved, land use controls would be needed to prevent access to the groundwater contamination.

6.3.3.3.2 Adequacy and Reliability of Controls

In-situ groundwater bioremediation should be effective for reducing COC concentrations to the MCLs in LHAAP-67 groundwater. However, optimum groundwater conditions would be required to increase the effectiveness of biological activity on these contaminants. More extensive treatability studies and further groundwater characterization are needed before designing the system. Pilot-scale studies would be needed to determine optimum DPT spacing and HRC® injection rates to determine if target redox conditions can be met for reductive dehalogenation. Occasional high concentrations of sulfate or oxidized iron and manganese in the aquifer matrix must be reduced before target contaminants can begin to be destroyed. For 1,1-DCE, application of additional materials such as KB-1 may be necessary. The success of these bioremediation technologies in high concentration areas may be limited due to the toxicity of the contaminants to the microorganisms. Also, because of the low groundwater velocity, a somewhat longer period of time is expected to be required for the treatment material to travel in the subsurface. Therefore, a grid spacing must be designed so that the HRC® migrates to all areas of contamination before it is consumed or degraded. The effectiveness of this technology at LHAAP-67 cannot be fully assessed until the treatability and pilot-scale studies have been completed.

Short-term land use controls would also prevent exposure to the groundwater COCs exceeding the MCLs during the time required to restore the groundwater through bioremediation. The reliability of land use controls would depend on the maintenance of the controls. Maintenance of the land use controls would not be required once MCLs for the COCs in groundwater are met at LHAAP-67. Compliance with the risk-reduction goals would be monitored and performance of the controls would be assessed throughout the duration of this alternative. The assessment may indicate the need for components of this alternative to be maintained, modified, or replaced.

6.3.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Provided the results of treatability testing are favorable, in-situ bioremediation would irreversibly reduce the toxicity, mobility and volume of the contaminants in LHAAP-67 groundwater. This alternative proposes that the groundwater COCs would be treated to the remediation levels, and therefore satisfies the USEPA statutory preference for remedial actions that permanently reduce contaminant toxicity, mobility and volume and utilize treatment as a principle element.

6.3.3.5 Short-Term Effectiveness

6.3.3.5.1 Protection of the Community During Remedial Action

This alternative is protective of the surrounding community during remedy implementation primarily because all activities would occur on site with very little disturbance of contaminated material.

6.3.3.5.2 Protection of Workers During Remedial Action

This alternative would involve potential short-term risks to workers associated with the operation of drilling equipment and potential exposure to contaminated groundwater during sampling activities. The implementation of an effective health and safety program would minimize potential short-term risks to remediation personnel. Remediation workers would conform to the site health and safety program and would be equipped with the necessary PPE. A site-specific health and safety plan would be prepared prior to implementing this alternative.

6.3.3.5.3 Short-Term Environmental Effects

Some minor clearing and grubbing to install monitoring wells or injection points for bioremediation of groundwater may be required. It is unlikely that there are any sensitive species that would be impacted. Should any sensitive species be found, the appropriate regulations and best management practices would be followed.

6.3.3.5.4 Duration of Remedial Activities

The duration of this alternative is approximately 6 years; 1 year for the treatability and pilot studies, 2 years to achieve MCLs after one HRC® injection, and 3 years of additional groundwater monitoring. Treatability and pilot studies are needed prior to the design of the in-situ bioremediation groundwater action. It is assumed that the treatability and pilot studies would be completed within the first year. The amount of time needed to meet groundwater remediation levels after HRC® injection would depend on the effectiveness of the treatment action, but is estimated to be 2 years based on first order anaerobic degradation rates and reasonable half-lives for the COCs; however, there is considerable uncertainty in this time estimate. Monitoring would be needed until remediation levels are met to determine trends in groundwater contamination levels and effectiveness of the remedial action. For this estimate, groundwater is assumed to continue for 3 years after the MCLs have been met throughout the plume. The monitoring time may increase or decrease depending on the effectiveness of the treatment method.

6.3.3.6 Implementability

6.3.3.6.1 Technical Feasibility

All components of this alternative are implementable. Minimal technical concerns exist that would hinder the implementation of this alternative. Routine maintenance of the land use controls would be required. The equipment and materials required for carbon source delivery are commercially available, but specialized knowledge of in-situ biological treatment would be required for implementation. Very few commercial vendors have the required expertise. A treatability study and pilot testing would be required to determine scale-up doses and treatment duration. With sufficient study, it is likely that an implementable design could be developed.

6.3.3.6.2 Administrative Feasibility

All actions under this alternative would be implemented on the site and thus do not require permits, though substantive provisions of permits that would otherwise be required are considered to be ARARs. By legal agreement (i.e., the FFA), the USEPA reviews and signs the ROD with TNRCC approval, thereby agreeing to the ARARs. By addressing the identified ARARs in the ROD and subsequent documents, it is anticipated that the alternative would adequately address all administrative barriers.

Land use controls, although administratively implementable, would require the following: development of an implementation plan; a site approval process to approve land-use changes to ensure the integrity of the controls; the installation of markers to identify areas of restricted use; training of appropriate personnel regarding the location and care of the controls; and internal notices to relevant regulatory offices of the existence of the land use controls. Approval by the USEPA and the State of Texas is required prior to the modification or termination of land use controls, implementation actions, or modification of land-use by the Army. The Army shall also seek concurrence from the USEPA and the State of Texas prior to any action that may disrupt the effectiveness of the land use controls or any action that may alter or negate the need for land use controls.

6.3.3.7 Cost

The total project present worth cost of Alternative 3 is approximately $1.68 million. The details of the cost estimates for all of the alternatives are presented in **Appendix A**.

6.3.3.7.1 Direct Capital Cost

The total direct capital cost is estimated at approximately $1.27 million. The direct capital cost includes the activities associated with land use controls (access controls), in-situ bioremediation, and monitoring well installation.

6.3.3.7.2 Indirect Capital Cost

The total indirect capital cost is estimated at approximately $310,000. Indirect costs include various regulatory and remedial design documents, the in-situ bioremediation treatability study and pilot study.

6.3.3.7.3 O&M Cost

The total O&M cost is estimated at approximately $344,000. The O&M cost includes long-term monitoring through year 6 associated with the land use controls and the assessment of in-situ bioremediation performance.

6.3.4 Alternative 4 – Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (Short Term)

This alternative reduces contamination throughout the groundwater plume via groundwater extraction and treatment to levels that would allow future unrestricted reuse of the site with no long-term reliance on land use controls. However, land use controls would be a significant component of this alternative in the short term until such time that the groundwater meets unrestricted residential cleanup goals (i.e., MCLs are achieved throughout the site). These actions would reduce COC concentrations in the groundwater to the MCLs throughout the site.

6.3.4.1 Overall Protection of Human Health and the Environment

6.3.4.1.1 Protection of Human Health

The remedial action proposed for this alternative could eventually remove the COCs present in groundwater above remediation levels established for LHAAP-67. Therefore, the residual site risk upon completion of these actions would be within the target risk range for an industrial user. Furthermore, since the MCLs would be achieved for the groundwater COCs, residual contamination after completion of the remedial actions would not limit the site's future use and would not require exposure limitations; therefore, the site could support unrestricted reuse and unlimited exposure with no long-term reliance on land use controls. This alternative is protective of human health and achieves the RAO for LHAAP-67.

6.3.4.1.2 Protection of the Environment

A site-wide ecological baseline risk assessment for the Group 4 sites is in progress; therefore, it is unknown what, if any, environmental receptors are at risk from exposure to the contaminants at LHAAP-67. The remedial measures implemented in this alternative, however, may provide certain levels of protection for potential environmental receptors. Restoration of LHAAP-67 groundwater would protect Central Creek from discharges of contaminated groundwater that could affect aquatic organisms.

6.3.4.2 Compliance with ARARs

6.3.4.2.1 Chemical-Specific ARARs

This alternative would comply with chemical-specific ARARs for groundwater throughout the site because the contaminant MCLs would be achieved, and would also protect the nearby surface water bodies from ARAR exceedances.

6.3.4.2.2 Location-Specific ARARs

The activities that would be conducted under this alternative would comply with all location-specific ARARs. No activities would take place in sensitive environments such as wetlands, and no impacts to archeological resources or threatened and endangered species are anticipated.

6.3.4.2.3 Action-Specific ARARs

The activities that would be conducted under this alternative would comply with all action-specific ARARs.

6.3.4.3 Long-Term Effectiveness and Permanence

6.3.4.3.1 Magnitude of Residual Risks

Upon completion of groundwater remediation, the residual site risk would be within the target risk range for an industrial user. Furthermore, since the MCLs would be achieved for groundwater COCs, residual contamination after completion of the remedial action would not limit the site's future use and would not require exposure limitations; therefore, the site could support unrestricted reuse and unlimited exposure with no long-term reliance on land use controls. The groundwater extraction and treatment at the existing plant would gradually restore the groundwater. Until the remediation levels are achieved, land use controls would be needed to prevent access to the groundwater contamination and disturbance of the extraction system.

6.3.4.3.2 Adequacy and Reliability of Controls

Groundwater extraction and treatment should be effective for reducing COC concentrations to the MCLs in LHAAP-67 groundwater. The existing groundwater treatment plant has been successfully operational for several years. There are significant issues associated with the effectiveness of groundwater extraction, especially associated with the use of extraction wells. If hydraulic conductivities are too low in the aquifer, only small volumes of groundwater can flow to the wells per unit time, which decreases the effectiveness of extraction. Narrow capture zones may not capture groundwater or excessive time may be required to capture all of the contamination. There are more pump maintenance issues associated with low flow conditions. The current extraction wells at a Group 2 site illustrate some of the difficulty associated with low flow conditions. Some of the extraction wells are usually dry which causes the pumps to overheat and fail to operate. A detailed pre-design study would be needed to determine the ideal extraction technique (wells or trenches) and the optimum configuration of wells and/or trenches for effective extraction of the LHAAP-67 groundwater.

Short-term land use controls would also prevent exposure to the groundwater COCs exceeding the MCLs during the time required to restore the groundwater through groundwater extraction. The reliability of land use controls would depend on the maintenance of the controls. Maintenance of the land use controls would not be required once MCLs for the COCs in groundwater are met at LHAAP-67. Consistent with the required 5-year CERCLA review, compliance with the risk-reduction goals would be monitored and performance of the controls would be assessed. The 5-year reviews may indicate the need for components of this alternative to be maintained, modified, or replaced.

6.3.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Implementation of groundwater extraction at LHAAP-67 would permanently reduce the toxicity, mobility, and volume of the groundwater contaminants in this area. The current ex-situ groundwater treatment plant would provide irreversible destruction of the COCs in the extracted groundwater. This alternative satisfies the USEPA statutory preference for remedial actions that permanently reduce the toxicity, mobility, and volume of the contaminants and utilize treatment as a principal element.

6.3.4.5 Short-Term Effectiveness

6.3.4.5.1 Protection of the Community During Remedial Action

This alternative is protective of the surrounding community during remedy implementation primarily because all activities would occur on site with very little disturbance of contaminated material.

6.3.4.5.2 Protection of Workers During Remedial Action

This alternative would involve potential short-term risks to workers associated with potential exposure to contaminated groundwater. Installation of the groundwater extraction system would require operation of construction equipment that would increase the risk to remediation workers. Other risks to workers include those generally associated with construction activities (e.g., slips, trips, and falls).

The implementation of proper engineering controls and safety equipment would minimize potential short-term risks to remediation personnel conducting the installation of the groundwater extraction system and groundwater sampling activities. Measures would be taken to prevent the contact of personnel with the extracted groundwater. Remediation workers would conform to the site health and safety program and would be equipped with the necessary PPE. A site-specific health and safety plan would be prepared prior to implementing this alternative.

6.3.4.5.3 *Short-Term Environmental Effects*

Some minor clearing and grubbing to install extraction wells and pipelines for groundwater recovery may be required. It is unlikely that any sensitive species would be impacted. Should any sensitive species be found, the appropriate regulations and best management practices would be followed.

6.3.4.5.4 *Duration of Remedial Activities*

Operation of the groundwater treatment system is planned to occur beyond the 30-year period used in the cost estimate for this FS. Preliminary calculations indicate that the required duration for groundwater extraction to achieve the MCLs in groundwater may be approximately 40 years. However, further study would be required to more accurately quantify this time frame. Continued monitoring would be conducted to assess trends in groundwater contamination levels and the effectiveness of the remedial action.

6.3.4.6 *Implementability*

6.3.4.6.1 *Technical Feasibility*

All components of this alternative are readily implementable. Minimal technical concerns exist that would hinder the implementation of this alternative. Routine inspection and maintenance of the land use controls would be required. All equipment, services and materials are readily available to conduct the activities for this alternative, and the groundwater treatment plant is already operational. Implementation of groundwater extraction at LHAAP-67 should be straightforward, although uncertainties exist regarding the ability of groundwater extraction to lower contaminant levels sufficiently to reach MCLs. The anticipated low groundwater yield could decrease the effectiveness of the extraction system. A detailed pre-design study would be needed to determine the ideal extraction technique (wells or trenches) and the optimum configuration of wells and/or trenches for effective extraction of the LHAAP-67 groundwater.

6.3.4.6.2 *Administrative Feasibility*

All actions under this alternative would be implemented on the site and thus do not require permits, though substantive provisions of permits that would otherwise be required are considered to be ARARs. By legal agreement (i.e., the FFA), the USEPA reviews and signs the ROD with TNRCC approval, thereby agreeing to the ARARs. By addressing the identified ARARs in the ROD and subsequent documents, it is anticipated that the alternative would adequately address all administrative barriers.

Short-term land use controls, although administratively implementable, would require the following: development of an implementation plan; a site approval process to approve land-use changes to ensure the integrity of the controls; the installation of markers to identify areas of restricted use; training of appropriate personnel regarding the location and care of the controls; and internal notices to relevant regulatory offices of the existence of the land use controls.

Approval by the USEPA and the State of Texas is required prior to the modification or termination of land use controls, implementation actions, or modification of land-use by the Army. The Army shall also seek concurrence from the USEPA and the State of Texas prior to any action that may disrupt the effectiveness of the land use controls or any action that may alter or negate the need for land use controls.

6.3.4.7 Cost

The total project present worth cost of Alternative 4 is approximately $1.74 million. The details of the cost estimates for all of the alternatives are presented in **Appendix A**.

6.3.4.7.1 Direct Capital Cost

The total direct capital cost is estimated at approximately $956,000. The direct capital cost includes the activities associated with land use controls (access controls), monitoring well installation and groundwater extraction system installation.

6.3.4.7.2 Indirect Capital Cost

The total indirect capital cost is estimated at approximately $168,000. The indirect costs include various work plans, remedial design documents and pre-design studies

6.3.4.7.3 O&M Cost

The total O&M cost is estimated at approximately $1.55 million. The O&M cost includes operation and maintenance of the groundwater extraction system throughout the 30-year evaluation period, and long-term monitoring through year 30 associated with the land use controls and assessment of groundwater extraction performance. Long-term monitoring conducted from year 1 through year 30 would support the required CERCLA 5-year reviews.

6.4 Comparative Analysis of Alternatives

6.4.1 Introduction

This section presents a comparative analysis of the remedial alternatives for LHAAP-67 according to the CERCLA evaluation criteria described in **Section 6.2**. This analysis is the second stage of the detailed evaluation process and provides information that forms the basis for selecting a preferred remedy.

This comparative analysis considers two of the three criteria categories, the threshold criteria and primary balancing criteria. The threshold category contains two criteria that must be satisfied by the selected alternative:

- Overall protection of human health and the environment and
- Compliance with ARARs.

These criteria are important because they reflect the key statutory mandates of CERCLA. If an alternative does not satisfy both of these criteria, it is not eligible to be selected.

The primary balancing category contains five criteria under which the relative advantages and disadvantages of the alternatives are compared to determine the most appropriate remedy. The five criteria are the following:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

The comparison of these five criteria for the alternatives forms the basis of the comparative analysis. The first and second balancing criteria address the statutory preference for treatment as a principal element of the remedy. Together with the third and fourth criteria, they form the basis for determining the general feasibility of each alternative and for determining whether costs are proportional to the overall effectiveness.

The two modifying criteria, state and community acceptance, must be satisfied if the alternative is to be accepted. The modifying criteria of state and community acceptance are typically not evaluated until the public has had an opportunity to comment on the proposed plan. Because specific alternatives have not been presented to the state and community, these two criteria are not formally compared in the FS.

A comparative analysis under the threshold and primary balancing criteria is presented in **Sections 6.4.2** and **6.4.3**, respectively, and is consistent with the format of the individual analysis of alternatives in **Section 6.3**.

6.4.2 Threshold Criteria

6.4.2.1 Overall Protection of Human Health and the Environment

The four alternatives provide varying levels of human health protection. Alternative 1, no action, does not achieve the RAO and provides the least protection of all the alternatives; it provides no reduction in risks to human health or the environment because no measures would be implemented to eliminate the pathway for human exposure to the groundwater contamination and potential groundwater impacts to Central Creek would not be addressed.

Alternatives 2, 3, and 4 all satisfy the RAO for LHAAP-67. Alternative 2, which relies the most heavily on land use controls and does not provide contaminant removal or treatment, would be protective of human health because the controls would prevent human access to the contaminated groundwater. The activities associated with the land use controls for Alternative 2 would monitor the migration of the groundwater contaminant plume, thereby protecting nearby surface water bodies. Alternatives 3 and 4 both provide a higher level of overall protection than Alternative 2 because the MCLs for the groundwater COCs would be achieved throughout the site, thereby eliminating unacceptable exposure risks. Furthermore, the restoration of LHAAP-67 groundwater according to Alternatives 3 and 4 would protect Central Creek from potential discharges of contaminated groundwater.

6.4.2.2 Compliance with ARARs

Alternative 1 does not comply with chemical-specific ARARs because no remedial action or measures would be implemented. Alternative 2 also does not comply with chemical-specific ARARs. Alternatives 3 and 4 comply with all chemical-specific ARARs for groundwater and surface water.

Location-specific and action-specific ARARs would not apply to Alternative 1 since no remedial activities would be conducted. Alternatives 2, 3, and 4 comply with all location-specific and action-specific ARARs.

6.4.3 Primary Balancing Criteria

6.4.3.1 Long-Term Effectiveness and Permanence

Alternative 1 would be the least effective and permanent in the long term because no contaminant removal or treatment would take place and no measures would be implemented to control exposure risks posed by contaminated site groundwater. Also, the potential exists for contaminated groundwater to migrate toward and discharge into Central Creek and then subsequently into Caddo Lake, a drinking water supply. However, the results of plume migration modeling indicate that the maximum concentrations of the COCs within Central Creek after plume impact would be below groundwater and surface water ARARs, which also would be protective of Caddo Lake. Alternative 2 offers a moderate degree of long-term effectiveness through the implementation of land use controls, which would minimize the potential risk posed by the contaminated groundwater and monitor potential groundwater impacts to Central Creek.

Alternatives 3 and 4 would significantly and permanently reduce groundwater contaminant concentrations to the MCLs, and therefore offer the highest degree of long-term effectiveness and permanence compared to the other alternatives. However, uncertainty exists regarding the ability of in-situ bioremediation or groundwater extraction to meet the MCLs for the groundwater COCs, and therefore further evaluation would be required. Should in-situ bioremediation or groundwater extraction be considered ineffective after implementation, the remedy or the remediation levels may need to be reevaluated. Although Alternatives 3 and 4 both rely on short-term land use controls until the MCLs are achieved through treatment, achieving the MCLs through in-situ bioremediation (Alternative 3) is expected to take less time than for groundwater extraction (Alternative 4), provided treatability testing is favorable.

6.4.3.2 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

Alternatives 1 and 2 do not employ treatment and would not result in a reduction of toxicity, mobility, or volume of contaminants.

Alternatives 3 and 4 would provide the greatest degree of permanent reduction in toxicity, mobility and volume of the groundwater contaminants. However, this reduction would only occur if the results of pre-design testing and further evaluations of in-situ bioremediation or groundwater extraction are favorable.

6.4.3.3 *Short-Term Effectiveness*

Because Alternative 1 does not involve any remedial measures, no short-term risk to workers, the community or the environment would exist. The activities associated with Alternative 2 would have little potential for short-term risk to workers or the environment, other than the minimal risks to workers associated with the exposure to contaminants during groundwater monitoring activities. Alternative 2 would provide almost immediate protection because the land use controls could be implemented relatively quickly, but maintenance of these controls would be required indefinitely.

Alternatives 3 and 4 both involve potential short-term risks to workers associated with exposure to contaminated groundwater and operation of drilling/construction equipment. The time period to achieve the groundwater remediation levels is the most significant difference between Alternatives 3 and 4. Alternative 3 is expected to take less time to achieve the remediation levels than Alternative 4, provided treatability testing for in-situ bioremediation is favorable. The implementation of Alternatives 3 and 4 would require more time than for Alternative 2 due to the requirement for a remedial design and pre-design testing.

6.4.3.4 *Implementability*

Under the no action alternative, no remedial action would be taken. Therefore, no difficulties or uncertainties would be associated with its implementation. Alternative 2 is easily implemented from a technical standpoint because no remedial activities would be performed, although routine maintenance of the land use controls, and sampling would be required.

Alternatives 3 and 4 are also technically implementable, although less so than Alternative 2 because of the uncertainties associated with the ability of in-situ bioremediation or groundwater extraction to lower contaminant levels sufficiently to reach the MCLs. Alternative 3 would be somewhat more difficult to implement than Alternative 4 from a technical standpoint due to the specialized expertise required to design and construct the in-situ bioremediation treatment elements.

Administratively, all of the alternatives are implementable.

6.4.3.5 Cost

Cost estimates are used in the CERCLA FS process to eliminate those remedial alternatives that are significantly more expensive than competing alternatives without offering commensurate increases in performance or overall protection of human health or the environment. The cost estimates developed are preliminary estimates with an intended accuracy range of +50 to –30 percent. Final costs will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final scope, final schedule, final engineering design, and other variables.

Costs developed are capital costs (including fixed-price remedial construction) and long-term O&M costs (post-remediation). Overall 30-year present worth costs are developed for each alternative assuming a discount rate of 7 percent. Total project present worth costs for each alternative is presented in **Appendix A**.

The progression of present worth costs from the least expensive alternative to the most expensive alternative is as follows: Alternative 1, Alternative 2, Alternative 3, and Alternative 4. No costs are associated with Alternative 1 because no remedial activities would be conducted. Alternative 2 has the lowest present worth and capital costs of the active remedial alternatives. The present worth cost for Alternatives 2 and 3 is lower than that of Alternative 4, primarily due to O&M of the groundwater extraction system under Alternative 4. The highest capital cost is associated with Alternative 3 primarily due to the activities associated with the injection phase of in-situ bioremediation.

7.0 References

Caddo Lake Institute (CLI), 1995, *Initial Species Inventory for Longhorn Army Ammunition Plant, Karnack, Texas*, June.

Cox, E., 2002, *Cost-Effective Bioremediation of Perchlorate in Soil & Groundwater,* Geosynthetic Consultants.

Gadus, E.F., Freeman, M.D., and Fields, R.C., 1998, *Archaeological Survey of 319 Hectares at the Longhorn Army Ammunition Plant, Harrison County, Texas,* June.

Geo-Marine Inc., 1996, *Draft Longhorn Army Ammunition Plant Cultural Resources Management Plan,* December.

Jacobs Engineering Group Inc. (Jacobs), 2001, *Remedial Investigation Report for the Group 2 Sites (Sites 12, 17, 18/24, 29, and 32) at the Longhorn Army Ammunition Plant, Karnack, Texas,* Final, St. Louis, MO, April.

Jacobs, 2002a, *Feasibility Study for the Group 4 Sites, Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunder's Branch, Central Creek, and Caddo Lake at the Longhorn Army Ammunition Plant, Karnack, Texas,* Draft, Oak Ridge, TN, August.

Jacobs, 2002b, *Final Remedial Investigation Report for the Group 4 Sites, Sites 35A, 35B, 35C, 46, 47, 48, 50 60, and Goose Prairie Creek, Longhorn Army Ammunition Plant, Karnack, TX*, Oak Ridge, TN, January.

Jacobs, 2002c, *Remedial Investigation Report Addendum for the Group 4 Sites (Sites 04, 08, 67) at the Longhorn Army Ammunition Plant, Karnack, Texas,* Final, Oak Ridge, TN, February.

Jacobs, 2003, *Baseline Human Health and Screening Ecological Risk Assessment for the Group 4 Sites (Sites 04, 08, 35A, 35B, 35C, 46, 47, 48, 50, 60, 67, Goose Prairie Creek, Saunder's Branch, Central Creek, and Caddo Lake), Longhorn Army Ammunition Plant, Karnack, Texas,* Final, Oak Ridge, TN, June.

McMahon, P.B., K.F. Denneky, and M.W. Sandstrom, 1999, "Hydraulic and Geochemical Performance of a Permeable Reactive Barrier Containing Zero-Valent Iron," *Ground Water, pp.* 37, 396–404, Denver Federal Center.

Pertulla, Timothy K. and Bo Nelson, 1999, *An Archaeological Survey of Harrison Bayou Lease Lands at the Longhorn Army Ammunition Plant, Harrison County, Texas,* Archaeological and Environmental Consultants, Report of Investigation No. 12, Caddo Lake Institute, Aspen Colorado, December.

Regenesis, 2002, "Designing Systems to Biologically Treat Perchlorate in Contaminated Water*,"* <*http://*www.regenesis.com> (2002).

Shaw 2005a, *Draft Final Data Gaps Investigation Report, Longhorn Army Ammunition Plant, Karnack, Texas*, May.

Shaw 2005b, *Draft Final Modeling Report, Delineation of Soil and Groundwater Concentrations Protective of Surface Water and Sediment, Longhorn Army Ammunition Plant, Karnack, Texas*, May.

Texas Natural Resource Conservation Commission (TNRCC), 2000, *Guidance for Screening and Assessing Texas Surface and Finished Drinking Water Quality Data*.

Texas Department of Parks and Wildlife, 2003, Correspondence from Celeste Brancel-Brown (Texas Department of Parks and Wildlife) to Mr. J. Marshall Davenport (Jacobs) regarding threatened and endangered species at Longhorn Army Ammunition Plant, February 6.

U.S. Army Corps of Engineers (USACE), 1992, *Longhorn Army Ammunition Plant RI/FS Work Plan,* Volume 1, General, Fort Worth District, June.

U.S. Environmental Protection Agency (USEPA), 1988a, *CERCLA Compliance With Other Laws Manual, Volume I,* OSWER Directive 9234.1-01, Washington, DC, August.

USEPA, 1988b, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final,* OSWER Directive 9355.3-01, Washington, DC.

USEPA, 1989a, *CERCLA Compliance with Other Laws Manual, Volume II,* OSWER Directive 9234.1-02, Washington, DC, August.

USEPA, 1989b, *CERCLA Compliance with State Requirements,* OSWER Directive 9234.2-05FS, Washington, DC, December.

USEPA, 1991, *ARARs Q's & A's: General Policy, RCRA, CWA, SDWA, Post-ROD Information, and Contingent Waivers*, OSWER Directive 9234.2-01FS-A, Washington, DC.

USEPA, 1994, *Water Quality Standards Handbook: Second Edition,* EPA/823-B-94-005a, Washington, DC, August.

U.S. Fish and Wildlife Service (USFWS), 2003, Correspondence from Mr. Thomas J. Cloud (USFWS) to Mr. J. Marshall Davenport (Jacobs Engineering Group Inc.) regarding threatened and endangered species at Longhorn Army Ammunition Plant, January 6.

USFWS, 2005, personal communication from Craig Giggleman (USFWS) to Dr. Rose Zeiler (U.S. Army Corps of Engineers), January 31.

Appendix A
Basis of Estimate for LHAAP-67 Remediation

BASIS OF ESTIMATE FOR
LHAAP-67 REMEDIATION, LHAAP-67 FS, LHAAP, KARNACK, TEXAS

The information included here is based on the cost estimate in Appendix A of the Group 4 Sites FS (Jacobs, 2002a)

Work Breakdown Structure

1.0	LHAAP-67 Remediation
1.10	Alternative 1, No Action
1.20	Alternative 2, Land Use Controls
1.30	Alternative 3, In-Situ Bioremediation, Land Use Controls (Short Term)
1.40	Alternative 4, Groundwater Extraction, On-Site Treatment, Surface Water Discharge, and Land Use Controls (Short Term)

1.XX.10	Regulatory Documents
1.XX.20	Remedial Design
1.XX.20.10	Remedial Design Documents
1.XX.20.20	Treatability and Pilot Studies
1.XX.30	Remedial Action
1.XX.30.10	General Contractor Construction Management
1.XX.30.20	Remediation
1.XX.30.20.10	Groundwater Remediation Cost
1.XX.30.20.10.10	Land Use Controls (Access Controls)
1.XX.30.20.10.20	Groundwater Extraction System Installation
1.XX.30.20.10.30	In-Situ Bioremediation
1.XX.30.20.10.40	Monitoring Wells Installation
1.XX.40	O&M
1.XX.40.10	Groundwater Treatment O&M Cost
1.XX.40.10.10	Long-Term Monitoring
1.XX.40.10.20	Extraction Wells O&M

Notes:

- "XX" represents the alternative number.

Accuracy of Estimate

- The estimate is being prepared from a CERCLA feasibility study. The accuracy of the estimate is +50 percent – 30 percent in accordance with CERCLA guidance. No contingency is included in the estimate.

General assumptions:

This section discusses assumptions used to generate the estimated and is not alternative-specific.

- No client's direct costs have been included in the estimates.
- Client will subcontract the remedial design, pre-engineering sampling and treatability studies.
- Client will subcontract remediation to a General Contractor. The General Contractor will subcontract to specialty subcontractors to perform different remediation tasks.
- O&M activities will be performed by a subcontractor for the client.
- Subcontractors to General Contractor will receive a 21.5 percent mark-up on labor, equipment, material and lower-tier subcontracts including disposal costs.
- General Contractor will receive a 15 percent mark-up on subcontractor cost. General Contractor will not receive 15 percent mark-up on his direct cost.
- Mark-up includes general overhead and profit.
- Construction Management WBS only includes General Contractor's direct cost plus his 15 percent mark-up on his subcontractors.
- Subcontractors performing O&M services for the client receive a 21.5 percent indirect mark-up.
- No indirect mark-up was applied to Regulatory Documents, Remedial Design, and Deed Restrictions.
- Sales Taxes have been applied on material only at 6.5 percent.

Labor Rates:

Labor rates used in the estimate are national averages and are not area specific. The labor rates include direct cost, fringes, employer liability and workmen's comprehension. Some rates as indicated below are fully burdened including indirect and profit. The following are the rates used in the estimate:

Laborer (L)	$19.36 per hour
Equipment Operator (OP)	$28.74 per hour
Pipe Fitter (PF)	$30.08 per hour
Electrician (E)	$30.18per hour
Truck Driver (TD)	$21.17 per hour
Engineer (Eng)	$65.00 per hour (Fully Burden Rate)
Superintendent- GC (Super)	$65.00 per hour (Fully Burden Rate)
Superintendent- SUB (Super)	$55.00 per hour
Technician (Tech)	$35.00 per hour
Technical Services Composite Rate (X-1)	$60.00 per hour (Fully Burden Rate)
Health & Safety Officer (H/S)	$45.00 per hour
Hazardous Material Tech. (HMT)	$40.00 per hour
Composite Construction Rate (X)	$25.00 per hour
Vendor Technical	$75.00 per hour

Material, Equipment and Production:

The material, equipment and production rates were generated using national averages obtained from nationally recognized cost references such as R.S. Means and Richardson.

The estimators used their experience to modify national average production rates for remedial action work. Most national cost references are based on the construction of facilities and not the remediation of existing facilities. Cost adjustments are required to reflect the actual estimated cost of the work.

Vendor Quotes:

Vendor quotes were used in the estimate for certain activities, which are not commonly found in cost references. These vendor quotes were based on the best available information at the time. The quotes could change based on final engineering associated with selected alternative. The following quote was obtained:

- Regenesis quote for HRC® purchase and injection

O&M Costs:

O&M costs do not include capital cost for the installation of equipment, wells or the modification of existing facilities. O&M costs will be assumed to go for 30 years from the beginning of the project unless otherwise specified in the alternative discussion part of the document.

Present Worth:

Present Worth is calculated based on the schedule in the alternative discussion section of the document. A 7 percent discount factor per year was used to calculate present worth.

Analytical Requirements:

Suite A	VOCs, pH, TDS, Temperature, Conductivity
Suite B	VOCs, dissolved oxygen, ORP, pH, temperature, ferrous iron, dissolved iron and manganese, nitrate, sulfate, sulfide, chloride, alkalinity, total organic carbon, metabolic acids (lactic, pruvic, acetic, propionic, and butyric), dissolved gases (carbon dioxide, methane, ethane, and ethene)
Suite C	VOC, SVOC, TCLP, and hazardous characteristics (i.e., ignitability, corrosivity, reactivity, and toxicity)

Longhorn Army Ammunition Plant
LHAAP-67 Remediation Cost Table
Alternative 2

WBS	Summary Description	Costs
Capital Costs		
1.20.10	Regulatory Documents	
1.20.20	**Remedial Design**	
1.20.20.10	Remedial Design Documents	
1.20.20.20	Treatability and Pilot Studies	
	Subtotal Indirect Costs	**$0**
1.20.30	**Remedial Action**	
1.20.30.10	General Contractor Construction Management	
1.20.30.20	**Remediation**	
1.20.30.20.10	**Groundwater Remediation Cost**	
1.20.30.20.10.10	Institutional Controls (Access Controls)	$15,000
1.20.30.20.10.20	Groundwater Extraction System Installation	
1.20.30.20.10.30	In Situ Bioremediation	
1.20.30.20.10.40	Monitoring Well Installation	$29,033
	Subtotal Direct Costs	**$44,033**
	Subtotal Capital Cost	**$44,033**
Operations and Maintenance		
1.20.40	**O&M**	
1.20.40.10	**Groundwater Treatment O&M Cost**	
1.20.40.10.10	Long Term Monitoring	$363,605
1.20.40.10.20	Extraction Wells O&M	
	Subtotal O&M Cost	**$363,605**
Total Cost		$407,637
Present Value for Capital		$41,152
Present Value for O&M		$180,314
Present Value Total		**$221,467**

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Alternative 2, Present Value
LHAAP-67 Feasibility Study

WBS NO. :

COMPANY NAME: **SHAW E&I**

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

FY	Capital Costs	O & M Costs						Present Value (NPV)		
								Discount Rate	Capital	O & M
		L T Monitor					Total	7%		
								NPV	41,152	180,314
2005	0	0					0			
2006	44,033	58,032					58,032			
2007	0	21,795					21,795			
2008	0	9,385					9,385			
2009	0	9,385					9,385			
2010	0	12,884					12,884			
2011	0	9,385					9,385			
2012	0	9,385					9,385			
2013	0	9,385					9,385			
2014	0	9,385					9,385			
2015	0	12,884					12,884			
2016	0	9,385					9,385			
2017	0	9,385					9,385			
2018	0	9,385					9,385			
2019	0	9,385					9,385			
2020	0	12,884					12,884			
2021	0	9,385					9,385			
2022	0	9,385					9,385			
2023	0	9,385					9,385			
2024	0	9,385					9,385			
2025	0	12,884					12,884			
2026	0	9,385					9,385			
2027	0	9,385					9,385			
2028	0	9,385					9,385			
2029	0	9,385					9,385			
2030	0	12,884					12,884			
2031	0	9,385					9,385			
2032	0	9,385					9,385			
2033	0	9,385					9,385			
2034	0	9,385					9,385			
2035	0	12,884					12,884			
	44,033	363,605	0	0	0	0	363,605			

**** WBS T O T A L ****

Alternative 2, Institutional Controls (Access Controls)
LHAAP-67 Feasibility Study

COMPANY NAME: **SHAW E&I**

WBS NO. : 1.20.30.20.10.10

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item				**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		
NO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT MH**	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**TOTAL ($)**
	Institutional Controls (Access Controls)														
1	Allowance for Legal Fees, Administration	1	lot		0			0		0		0	15,000	15,000	15,000
	Controls, and Documentation														
	Subtotal							**0**		**0**		**0**		**15,000**	**15,000**
	Taxes @ 6.5%									0					0

** WBS T O T A L ** **$ 15,000**

Alternative 2, Monitoring Wells Installation
LHAAP-67 Feasibility Study

COMPANY NAME: **SHAW E&I**

WBS NO. :1.20.30.20.10.40

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Install new monitoring wells														
	LHAAP-67--2 wells														
	Total wells ---2 ea.														
	General conditions														
1	Safety, training, waste, health plans, etc.	1	ea	80	80	eng	65.00	5,200	200	200		0		0	5,400
2	Mob/demob	1	ea	16	16	hmt/eng	52.50	840	400	400	500	500		0	1,740
3	Survey crew	1	day		0			0		0		0	950	950	950
4	Site orientation - 1 day	3	pers	8	24	op	28.74	690		0		0		0	690
5	Hazardous material technician	1	ea	24	24	hmt	40.00	960	100	100		0		0	1,060
6	Geologist	1	ea	24	24	eng	65.00	1,560		0	0	0		0	1,560
	Field Work														
1	Install monitoring wells, 25' ave, dp., 4" dia. S.S.	2	ea		0			0		0		0	5,000	10,000	10,000
2	Well drill waste disposal	6	drum		0			0		0		0	250	1,500	1,500
3	Sample analysis (Suite C)	2	ea		0			0		0		0	475	950	950
	Subtotal							**9,250**		**700**		**500**		**13,400**	**23,850**
	Taxes @ 6.5 %									46					46
	Subtotal														**23,895**
	Indirects @ 21.5%														5,137

** WBS T O T A L ** **$ 29,033**

Alternative 2, Long-Term Monitoring
LHAAP-67 Feasibility Study

COMPANY NAME: SHAW E&I
WBS NO. : 1.20.40.10.10
PROJECT LOCATION: KARNACK, TEXAS
DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Monitoring of 4 wells														
	Year 1														
1	Establish initial database, licenses, coordinate well characterization & other well info, develop work plans, etc	1	ea	300	300	eng	65.00	19,500	5,000	5,000		0	5,000	5,000	29,500
2	Collect and prepare samples quarterly (GW)	16	ea	16	256	tech	35.00	8,960	110	1,760	36	576		0	11,296
3	Sample analysis (Suite A)	16	ea		0			0		0		0	138	2,208	2,208
4	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**32,620**		**6,910**		**576**		**7,208**	**47,314**
	Taxes @ 6.5 %									449					449
	Subtotal														**47,763**
	Indirects @ 21.5%														10,269
	Year 1 Total														**$ 58,032**
	Year 2														
1	Collect and prepare samples quarterly (GW)	16	ea	16	256	tech	35.00	8,960	110	1,760	36	576		0	11,296
2	Sample analysis (Suite A)	16	ea		0			0		0		0	138	2,208	2,208
3	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**13,120**		**1,910**		**576**		**2,208**	**17,814**
	Taxes @ 6.5 %									124					124
	Subtotal														**17,938**
	Indirects @ 21.5%														3,857
	Year 2 Total														**$ 21,795**
	Years 3 - 4														
1	Collect and prepare samples annually (GW)	8	ea	16	128	tech	35.00	4,480	110	880	36	288		0	5,648
2	Sample analysis (Suite A)	8	ea		0			0		0		0	138	1,104	1,104
3	Annual report	2	ea	64	128	eng	65.00	8,320	150	300		0		0	8,620
	Subtotal							**12,800**		**1,180**		**288**		**1,104**	**15,372**
	Taxes @ 6.5 %									77					77
	Subtotal														**15,449**
	Indirects @ 21.5%														3,321
	Years 3 - 4 Total														**$ 18,770**

Alternative 2, Long-Term Monitoring
LHAAP-67 Feasibility Study

COMPANY NAME: SHAW E&I

WBS NO. : 1.20.40.10.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Year 5														
1	Collect and prepare samples Year 5 (GW)	4	ea	16	64	tech	35.00	2,240	110	440	36	144		0	2,824
2	Sample analysis (Suite A)	4	ea		0			0		0		0	138	552	552
3	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
4	CERCLA 5-year review	1	ea	48	48	X-1	60.00	2,880		0		0	0	0	2,880
	Subtotal							**9,280**		**590**		**144**		**552**	**10,566**
	Taxes @ 6.5 %									38					38
	Subtotal														**10,604**
	Indirects @ 21.5%														2,280
	Year 5 Total														**$ 12,884**
	Years 6-9, 11-14, 16-19, 21-24, 26-29														
1	Collect and prepare samples annually (GW)	80	ea	16	1280	tech	35.00	44,800	110	8,800	36	2,880		0	56,480
	for monitoring wells (4 wells)														
2	Sample analysis (Suite A) annually (excluding samples	80	ea		0			0		0		0	138	11,040	11,040
3	Annual report	20	ea	64	1280	eng	65.00	83,200	150	3,000		0		0	86,200
	Subtotal							**128,000**		**11,800**		**2,880**		**11,040**	**153,720**
	Taxes @ 6.5 %									767					767
	Subtotal														**154,487**
	Indirects @ 21.5%														33,215
	Years 6-9, 11-14, 16-19, 21-24, 26-29 Total														**$ 187,702**
	Years 10, 15, 20, 25, 30														
1	Collect and prepare samples annually (GW)	20	ea	16	320	tech	35.00	11,200	110	2,200	36	720		0	14,120
	for monitoring wells (4 wells)														
2	Sample analysis (Suite A) every 5 years (GW)	20	ea		0			0		0		0	138	2,760	2,760
3	Annual report	5	ea	64	320	eng	65.00	20,800	150	750		0		0	21,550
4	CERCLA 5-year review	5	ea	48	240	X-1	60.00	14,400		0		0	0	0	14,400
	Subtotal							**46,400**		**2,950**		**720**		**2,760**	**52,830**
	Taxes @ 6.5 %									192					192
	Subtotal														**53,022**
	Indirects @ 21.5%														11,400
	Years 10, 15, 20, 25, 30 Total														**$ 64,421**

**** WBS T O T A L **** **$ 363,605**

Longhorn Army Ammunition Plant
LHAAP-67 Remediation Cost Table
Alternative 3

WBS	Summary Description	Costs
Capital Costs		
1.30.10	Regulatory Documents	$44,478
1.30.20	**Remedial Design**	
1.30.20.10	Remedial Design Documents	$83,372
1.30.20.20	Treatability and Pilot Studies	$182,250
	Subtotal Indirect Costs	**$310,100**
1.30.30	**Remedial Action**	
1.30.30.10	General Contractor Construction Management	$297,348
1.30.30.20	**Remediation**	
1.30.30.20.10	**Groundwater Remediation Cost**	
1.30.30.20.10.10	Institutional Controls (Access Controls)	$15,000
1.30.30.20.10.20	Groundwater Extraction System Installation	
1.30.30.20.10.30	In Situ Bioremediation	$900,646
1.30.30.20.10.40	Monitoring Well Installation	$56,826
	Subtotal Direct Costs	**$1,269,820**
	Subtotal Capital Cost	**$1,579,920**
Operations and Maintenance		
1.30.40	**O&M**	
1.30.40.10	**Groundwater Treatment O&M Cost**	
1.30.40.10.10	Long Term Monitoring	$343,761
1.30.40.10.20	Extraction Wells O&M	
	Subtotal O&M Cost	**$343,761**
Total Cost		$1,923,681
Present Value for Capital		$1,399,840
Present Value for O&M		$275,228
Present Value Total		**$1,675,069**

Alternative 3, Present Value

WBS NO. :

COMPANY NAME: SHAW E & I

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

FY	Capital Costs	O & M Costs		Present Value (NPV)		
				Discount Rate	Capital	O & M
		L T Monitor	Total	7%		
				NPV	1,399,840	275,228
2004	0	0	0			
2005	325,100	0	0			
2006	1,254,820	135,246	135,246			
2007	0	80,257	80,257			
2008	0	42,753	42,753			
2009	0	42,753	42,753			
2010	0	42,753	42,753			
	1,579,920	343,761	343,761			

** WBS T O T A L **

Alternative 3, Regulatory Documents

COMPANY NAME: SHAW E & I

WBS NO.: 1.30.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Regulatory Documents														
1	Remedial Action Work Plan	1	ea	240	240	X1	60.00	14,400	400	400		0		0	14,800
2	Remedial Action Work Report	1	ea	480	480	X1	60.00	28,800	800	800		0		0	29,600
	Subtotal							**43,200**		**1,200**		**0**		**0**	**44,400**
	Taxes @ 6.5 %									78					78

** WBS TOTAL ** **$ 44,478**

Alternative 3, Remedial Design Documents

COMPANY NAME: SHAW E & I

WBS NO. : 1.30.20.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Engineering Support														
1	Develop design report, drawings, specs & procurement pkgs.	1	lot	1000	1000	eng	65.00	65,000	1,000	1,000		0	1,600	1,600	67,600
2	RFP & S/C procurement doc. support	1	ea	200	200	eng	65.00	13,000	100	100		0		0	13,100
3	Bid and award S/C support	1	ea	40	40	eng	65.00	2,600		0		0		0	2,600
	Subtotal							**80,600**		**1,100**		**0**		**1,600**	**83,300**
	Taxes @ 6.5 %									72					72

** WBS T O T A L ** **$ 83,372**

Alternative 3, Treatability and Pilot Studies

COMPANY NAME: **SHAW E & I**

WBS NO. : 1.30.20.20

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item NO	**DESCRIPTION**	**QTY**	**UNIT**	**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		**TOTAL ($)**
				UNIT MH	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	
	In Situ Biological Treatability Study for LHAAP-67														
1	Bench scale testing	1	lot		0			0		0		0	20,000	20,000	20,000
2	Sample collection, analysis, and other	1	lot		0			0		0		0	10,000	10,000	10,000
	support activities														
3	Prepare report	1	ea		0			0		0		0	5,000	5,000	5,000
	In Situ Biological Treatment Pilot Study for LHAAP-67														
1	Install pilot test treatment system at LHAAP-67	1	lot		0			0		0		0	100,000	100,000	100,000
	and monitor/sample for approx 1 year														
2	Prepare report	1	ea		0			0		0		0	15,000	15,000	15,000
	Subtotal				**0**			**0**		**0**		**0**		**150,000**	**150,000**
	Taxes @ 6.5 %							0							0
	Subtotal														**150,000**
	Indirects @ 21.5%														32,250

**** WBS T O T A L **** **$ 182,250**

Alternative 3, General Contractor Construction Management

WBS NO. : 1.30.30.10

COMPANY NAME: **SHAW E & I**

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item				**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		
NO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT MH**	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**TOTAL ($)**
	Construction Management														
1	Temporary facilities	4.5	mo					0		0		0	750	3,375	3,375
2	Equipment	4.5	mo					0		0	600	2,700		0	2,700
3	Field support/superintendent	4.5	mo	173	2,076	super	65.00	134,940		0	2,825	12,713		0	147,653
4	G & A/overhead/profit/bond @ 15 % of construction costs	15.00%						0		0		0	957,472	143,621	143,621
	Subtotal							**134,940**		**0**		**15,413**		**146,996**	**297,348**
	Taxes @ 6.5 %									0					0

**** WBS T O T A L **** **$ 297,348**

Alternative 3, Institutional Controls (Access Controls)

WBS NO. : 1.30.30.20.10.10

COMPANY NAME: **SHAW E & I**

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item				**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		
NO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT MH**	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**TOTAL ($)**
	Institutional Controls (Access Controls)														
1	Allowance for legal fees, administration	1	lot		0			0		0		0	15,000	15,000	15,000
	controls, and documentation														
	Subtotal							**0**		**0**		**0**		**15,000**	**15,000**
	Taxes @ 6.5%									0					0

** WBS T O T A L ** **$ 15,000**

Alternative 3, In Situ Bioremediation

COMPANY NAME: SHAW E & I

WBS NO. :1.30.30.20.10.30

PROJECT LOCATION: KARNACK, TEXAS DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	General conditions														
1	Safety, training, waste, health plans, etc.	1	ea	80	80	eng	65.00	5,200	200	200		0		0	5,400
2	Mob/demob	1	ea	60	60	op	28.74	1,724	1,200	1,200	1,000	1,000		0	3,924
3	Port-let rental-2 ea	4	mo		0			0		0		0	320	1,280	1,280
4	Office/change house trailer set-up/utilities	1	ea	80	80	op	28.74	2,299	3,000	3,000	300	300		0	5,599
5	Trailer rental-1 ea	4	mo		0			0	50	200		0	315	1,260	1,460
6	Survey crew	10	day		0			0		0		0	950	9,500	9,500
7	Construction equip. staging area	1	ea	40	40	op	28.74	1,150	500	500	692	692		0	2,342
8	Site Orientation - 1 day	10	pers	8	80	op	28.74	2,299		0		0		0	2,299
9	Health & safety officer	4	mo	173	692	h/s	45.00	31,140	50	200	160	640		0	31,980
10	Hazardous material technician	4	mo	173	692	hmt	40.00	27,680	100	400		0		0	28,080
11	Site Superintendent	4	mo	173	692	super	50.00	34,600		0	2825	11,300		0	45,900
	Decontamination area														
1	Provide small temporary decon area for	1	ea	24	24	x	25.00	600	1,000	1,000	500	500		0	2,100
	decon of const. equipment														
2	Decon all equipment at completion of work	1	lot	24	24	l	19.36	465	500	500	400	400		0	1,365
3	Pressure washer	1	ea		0			0			650	650		0	650
	Field Work														
1	Silt fence at construction area	2,100	lf	0.02	42	l	19.36	813	0.40	840	0.05	105		0	1,758
2	Erosion control, straw bales at const. area	1	lot	150	150	l	19.36	2,904	5,000	5,000		0		0	7,904
3	Clear/grub areas for access by direct push	1	ac	60	60	op	28.74	1,724		0	3,200	3,200		0	4,924
	technology equipment to areas being treated	1	ac	80	80	l	19.36	1,549		0		0		0	1,549
4	Fertilize, seed, and mulch	43	msf	0.60	26	l	19.36	499	30	1,290	9	387		0	2,176

Alternative 3, In Situ Bioremediation

COMPANY NAME: **SHAW E & I**

WBS NO. :1.30.30.20.10.30

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item				**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		
NO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT MH**	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**TOTAL ($)**
	In Situ Biological Treatment														
1	DPT injection of nutrients (per Regenesis, Inc.)	1	lot					0		0		0	580,150	580,150	580,150
	Subtotal							**114,647**		**14,330**		**19,174**		**592,190**	**740,341**
	Taxes @ 6.5 %									931					931
	Subtotal														**741,272**
	Indirects @ 21.5%														159,374

** WBS T O T A L ** **$ 900,646**

Alternative 3, Monitoring Wells Installation

WBS NO. :1.30.30.20.10.40

COMPANY NAME: **SHAW E & I**

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Install new monitoring wells														
	LHAAP-67--5 wells														
	Total wells ---5 ea.														
	General conditions														
1	Safety, training, waste, health plans, etc.	1	ea	80	80	eng	65.00	5,200	200	200		0		0	5,400
2	Mob/demob	1	ea	16	16	hmt/eng	52.50	840	400	400	500	500		0	1,740
3	Survey crew	1	day		0			0		0		0	950	950	950
4	Site Orientation - 1 day	3	pers	8	24	op	28.74	690		0		0		0	690
5	Hazardous material technician	1	ea	64	64	hmt	40.00	2,560	100	100		0		0	2,660
6	Geologist	1	ea	64	64	eng	65.00	4,160		0	0	0		0	4,160
	Field Work														
1	Install monitoring wells, 25' ave, dp., 4" dia. S.S.	5	ea		0			0		0		0	5,000	25,000	25,000
2	Well drill waste disposal	15	drum		0			0		0		0	250	3,750	3,750
3	Sample analysis (Suite C)	5	ea		0			0		0		0	475	2,375	2,375
	Subtotal							**13,450**		**700**		**500**		**32,075**	**46,725**
	Taxes @ 6.5 %									46					46
	Subtotal														**46,770**
	Indirects @ 21.5%														10,056

** WBS T O T A L ** **$ 56,826**

Alternative 3, Long-Term Monitoring

WBS NO. : 1.30.40.10.10

COMPANY NAME: SHAW E & I

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Monitoring of 12 wells														
	Year 2														
1	Establish initial database, licenses, coordinate	1	ea	300	300	eng	65.00	19,500	5,000	5,000		0	5,000	5,000	29,500
	well characterization & other well info,														
	develop work plans, etc														
2	Collect and prepare samples - 5 events (GW)	60	ea	16	960	tech	35.00	33,600	110	6,600	36	2,160		0	42,360
3	Sample analysis (Suite B)	60	ea		0			0		0		0	573	34,380	34,380
4	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**57,260**		**11,750**		**2,160**		**39,380**	**110,550**
	Taxes @ 6.5 %									764					764
	Subtotal														**111,314**
	Indirects @ 21.5%														23,932
	Year 2 total														**$ 135,246**
	Year 3														
1	Collect and prepare samples quarterly (GW)	48	ea	16	768	tech	35.00	26,880	110	5,280	36	1,728		0	33,888
2	Sample analysis (Suite B)	48	ea		0			0		0		0	573	27,504	27,504
3	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**31,040**		**5,430**		**1,728**		**27,504**	**65,702**
	Taxes @ 6.5 %									353					353
	Subtotal														**66,055**
	Indirects @ 21.5%														14,202
	Year 3 total														**$ 80,257**

Alternative 3, Long-Term Monitoring

COMPANY NAME: SHAW E & I

WBS NO. : 1.30.40.10.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Years 4-6														
1	Collect and prepare samples semi-annually (GW)	72	ea	16	1152	tech	35.00	40,320	110	7,920	36	2,592		0	50,832
	for monitoring wells (12 wells)														
2	Sample analysis (Suite B) semi-annually (GW)	72	ea		0			0		0		0	573	41,256	41,256
3	Annual report	3	ea	64	192	eng	65.00	12,480	150	450		0		0	12,930
	Subtotal							**52,800**		**8,370**		**2,592**		**41,256**	**105,018**
	Taxes @ 6.5 %									544					544
	Subtotal														**105,562**
	Indirects @ 21.5%														22,696
	Years 4-6 total														**$ 128,258**

**** WBS T O T A L **** **$ 343,761**

Longhorn Army Ammunition Plant
LHAAP-67 Remediation Cost Table
Alternative 4

WBS	Summary Description	Costs
Capital Costs		
1.40.10	Regulatory Documents	$44,478
1.40.20	**Remedial Design**	
1.40.20.10	Remedial Design Documents	$123,500
1.40.20.20	Treatability and Pilot Studies	
	Subtotal Indirect Costs	**$167,978**
1.40.30	**Remedial Action**	
1.40.30.10	General Contractor Construction Management	$250,925
1.40.30.20	**Remediation**	
1.40.30.20.10	**Groundwater Remediation Cost**	
1.40.30.20.10.10	Institutional Controls (Access Controls)	$15,000
1.40.30.20.10.20	Groundwater Extraction System Installation	$632,908
1.40.30.20.10.30	In Situ Bioremediation	
1.40.30.20.10.40	Monitoring Well Installation	$56,826
	Subtotal Direct Costs	**$955,659**
	Subtotal Capital Cost	**$1,123,637**
Operations and Maintenance		
1.40.40	**O&M**	
1.40.40.10	**Groundwater Treatment O&M Cost**	
1.40.40.10.10	Long Term Monitoring	$586,980
1.40.40.10.20	Extraction Wells O&M	$967,142
	Subtotal O&M Cost	**$1,554,123**
Total Cost		$2,677,760
Present Value for Capital		$1,050,128
Present Value for O&M		$691,010
Present Value Total		**$1,741,138**

Alternative 4, Present Value
LHAAP-67 Feasibility Study

WBS NO. :

COMPANY NAME: SHAW E&I

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

FY	Capital Costs	O & M Costs			Present Value (NPV)		
					Discount Rate	Capital	O & M
		L T Monitor	Extract Well	Total	7%		
					NPV	1,050,128	691,010
2004	0	0	0	0			
2005	1,123,637	82,852	32,238	115,090			
2006	0	46,614	32,238	78,852			
2007	0	15,590	32,238	47,828			
2008	0	15,590	32,238	47,828			
2009	0	19,089	32,238	51,327			
2010	0	15,590	32,238	47,828			
2011	0	15,590	32,238	47,828			
2012	0	15,590	32,238	47,828			
2013	0	15,590	32,238	47,828			
2014	0	19,089	32,238	51,327			
2015	0	15,590	32,238	47,828			
2016	0	15,590	32,238	47,828			
2017	0	15,590	32,238	47,828			
2018	0	15,590	32,238	47,828			
2019	0	19,089	32,238	51,327			
2020	0	15,590	32,238	47,828			
2021	0	15,590	32,238	47,828			
2022	0	15,590	32,238	47,828			
2023	0	15,590	32,238	47,828			
2024	0	19,089	32,238	51,327			
2025	0	15,590	32,238	47,828			
2026	0	15,590	32,238	47,828			
2027	0	15,590	32,238	47,828			
2028	0	15,590	32,238	47,828			
2029	0	19,089	32,238	51,327			
2030	0	15,590	32,238	47,828			
2031	0	15,590	32,238	47,828			
2032	0	15,590	32,238	47,828			
2033	0	15,590	32,238	47,828			
2034	0	19,089	32,238	51,327			
	1,123,637	586,980	967,142	1,554,123			

** WBS T O T A L **

Alternative 4, Regulatory Documents
LHAAP-67 Feasibility Study

COMPANY NAME: **SHAW E&I**

WBS NO.: 1.40.10

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT MH**	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**TOTAL ($)**
	Regulatory Documents														
1	Remedial Action Work Plan	1	ea	240	240	X1	60.00	14,400	400	400		0		0	14,800
2	Remedial Action Work Report	1	ea	480	480	X1	60.00	28,800	800	800		0		0	29,600
	Subtotal							**43,200**		**1,200**		**0**		**0**	**44,400**
	Taxes @ 6.5 %									78					78

** WBS T O T A L ** **$ 44,478**

Alternative 4, Remedial Design Documents
LHAAP-67 Feasibility Study

COMPANY NAME: SHAW E&I

WBS NO. : 1.40.20.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Engineering Support														
1	Develop design report, drawings, specs & procurement pkgs.	1	lot	1,600	1600	eng	65.00	104,000	2,000	2,000		0	1,600	1,600	107,600
2	RFP & S/C procurement doc. support	1	ea	200	200	eng	65.00	13,000	160	160		0		0	13,160
3	Bid and award S/C support	1	ea	40	40	eng	65.00	2,600		0		0		0	2,600
	Subtotal							**119,600**		**2,160**		**0**		**1,600**	**123,360**
	Taxes @ 6.5 %									140					140

** WBS T O T A L ** **$ 123,500**

Alternative 4, General Contractor Construction Management
LHAAP-67 Feasibility Study

WBS NO. : 1.40.30.10

COMPANY NAME: **SHAW E&I**

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Construction Management														
1	Temporary facilities	3	mo					0		0		0	750	2,250	2,250
2	Equipment	3	mo					0		0	600	1,800		0	1,800
3	Field support / superintendent	3	mo	173	2,076	super	65.00	134,940		0	2,825	8,475		0	143,415
4	G & A/overhead/profit/bond @ 15 % of	15.00%						0		0		0	689,734	103,460	103,460
	construction costs														
	Subtotal							**134,940**		**0**		**10,275**		**105,710**	**250,925**
	Taxes @ 6.5 %									0					0

**** WBS T O T A L **** **$ 250,925**

Alternative 4, Institutional Controls (Access Controls)
LHAAP-67 Feasibility Study

COMPANY NAME: **SHAW E&I**

WBS NO. : 1.40.30.20.10.10

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item NO	**DESCRIPTION**	**QTY**	**UNIT**	**LABOR**					**MATERIAL**		**EQUIPMENT**		**SUBCONTRACT**		**TOTAL ($)**
				UNIT MH	**TOTAL MH**	**CRAFT**	**$/MH**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	**$/UNIT**	**$ VALUE**	
	Institutional Controls (Access Controls)														
1	Allowance for legal fees, administration controls, and documentation	1	lot		0			0		0		0	15,000	15,000	15,000
	Subtotal							**0**		**0**		**0**		**15,000**	**15,000**
	Taxes @ 6.5%									0					0

** WBS T O T A L ** **$ 15,000**

Alternative 4, Groundwater Extraction System Installation Wells Installation
LHAAP-67 Feasibility Study

COMPANY NAME: **SHAW E&I**

WBS NO. :1.40.30.20.10.10

PROJECT LOCATION: **KARNACK, TEXAS** **DATE:** **AUGUST 2005**

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Convert Existing Monitoring Wells into														
	Extraction Wells														
	LHAAP-67 (2 wells)														
	Total ---2 wells														
	Install New Extraction Wells														
	LHAAP-67 (9 wells)														
	Total ---9 wells														
	General conditions														
1	Safety, training, waste, health plans, etc.	1	ea	80	80	eng	65.00	5,200	200	200		0		0	5,400
2	Site orientation, training, etc	4	pers	8	32	pf	30.08	963		0		0		0	963
3	Mob/demob	1	ea	60	60	op	28.74	1,724	1,200	1,200	1,000	1,000		0	3,924
4	Office/change house trailer set-up/utilities	1	ea	80	80	op	28.74	2,299	3,000	3,000	300	300		0	5,599
5	Trailer rental-1 ea	2.5	mo		0			0	50	125		0	315	788	913
6	Port-let rental-2 ea	2.5	mo		0			0		0		0	320	800	800
7	Construction equip. staging area	1	ea	40	40	op	28.74	1,150	500	500	692	692		0	2,342
8	Health & safety officer	2.5	mo	173	2,076	h/s	45.00	93,420	50	125	160	400		0	93,945
9	Site superintendent	2.5	mo	173	2,076	super	50.00	103,800		0	2,825	7,063			110,863
	Decontamination area														
1	Provide small temporary decon area for	1	ea	24	24	x	25.00	600	1,000	1,000	500	500		0	2,100
	decon of const. equipment. Demo at end of job.														
2	Decontaminate all equipment at completion of work	1	lot	24	24	l	19.36	465	500	500	400	400		0	1,365
3	Pressure washer	1	ea		0			0			650	650		0	650

Alternative 4, Groundwater Extraction System Installation Wells Installation
LHAAP-67 Feasibility Study

COMPANY NAME: SHAW E&I

WBS NO. :1.40.30.20.10.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Field Work														
1	Silt fence at construction areas	2,100	lf	0.02	42	l	19.36	813	0.40	840	0.05	105		0	1,758
2	Erosion control, straw bales at const. area	1	lot	150	150	l	19.36	2,904	5,000	5,000		0		0	7,904
3	Clear & prepare well site	11	ea	48	528	op	28.74	15,175	120	1,320	900	9,900		0	26,395
4	Modify exist well, install new well pump,	2	ea	80	160	pf	30.08	4,813	3,500	7,000	250	500		0	12,313
	power, discharge piping, level controls, etc														
5	Install extraction wells, 25' ave. dp., 4" dia. S.S.	9	ea		0			0		0		0	5,000	45,000	45,000
6	Well drill waste disposal	27	drum		0			0		0		0	250	6,750	6,750
7	Collect & prepare well waste drum samples	9	ea	12	108	tech	35.00	3,780	60	540	36	324		0	4,644
8	Sample analysis (Suite C)	9	ea		0			0		0		0	475	4,275	4,275
9	Pipe trench excavation (9,600 lf)	2,845	bcy	0.08	228	op	28.74	6,541		0	3.70	10,527		0	17,068
10	Sand bedding for pipe, compacted	356	lcy	0.25	89	op	28.74	2,555	3.70	1,316	2.15	764		0	4,635
11	Backfill and compaction , 6" lifts	3,058	lcy	0.06	184	op	28.74	5,274		0	2.75	8,411		0	13,684
12	Pipe 4" dia HPDE w/fittings	9,600	lf	0.10	960	pf	30.08	28,877	1.70	16,320	1.15	11,040		0	56,237
13	Backflow preventor (check) valves, 4" dia	11	ea	8	88	pf	30.08	2,647	895	9,845		0		0	12,492
14	Air release valves w/fittings	4	ea	8	32	pf	30.08	963	340	1,360		0		0	2,323
15	Pressure relief valves w/fittings	2	ea	8	16	pf	30.08	481	380	760		0		0	1,241
16	Clean out 4" dia	9	ea	6	54	pf	30.08	1,624	65	585		0		0	2,209
17	Gate Valves, 4" dia.	13	ea	6	78	pf	30.08	2,346	465	6,045		0		0	8,391
18	Vault-precast concrete w/secure lid for all valves	12	ea	16	192	op	28.74	5,518	320	3,840		0		0	9,358
19	Booster pump, 1 HP, 11 GPM, 50' head w/fittings	1	ea	24	24	pf	30.08	722	1,500	1,500		0		0	2,222
20	Vault-precast conc., water tight for booster pump	1	ea	64	64	op	28.74	1,839	3,500	3,500		0		0	5,339
21	Electrical power line w/poles to well areas	750	lf	0.04	30	e	30.18	905	3.50	2,625	1.35	1,013		0	4,543
22	Electrical power line w/poles to booster pumps	250	lf	0.04	10	e	30.18	302	3.50	875	1.35	338		0	1,514
23	Electrical conduit, disconnects, etc. at booster pump	1	ea	48	48	e	30.18	1,449	750	750		0		0	2,199
24	Electrical conduit, disconnects, etc. at wells	11	ea	32	352	e	30.18	10,623	500	5,500		0		0	16,123
25	Fertilize, seed, and mulch	15	msf	0.60	9	l	19.36	174	30	450	9	135		0	759
26	Misc. support personnel for above activities	600	hrs	1	600	l	19.36	11,616	2.50	10	10.11	6,066		0	17,692
	Subtotal							**321,562**		**76,631**		**60,126**		**57,613**	**515,931**
	Taxes @ 6.5 %									4,981					4,981
	Subtotal														**520,912**
	Indirects @ 21.5%														111,996

** WBS T O T A L ** $ **632,908**

Alternative 4, Monitoring Wells Installation
LHAAP-67 Feasibility Study

WBS NO. :1.40.30.20.10.40

COMPANY NAME: **SHAW E&I**

PROJECT LOCATION: **KARNACK, TEXAS**

DATE: **AUGUST 2005**

Item NO	DESCRIPTION	QTY	UNIT	LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		TOTAL ($)
				UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	
	Install new monitoring wells														
	LHAAP-67 (5 wells)														
	Total wells ---5														
	General conditions														
1	Safety, training ,waste, health plans, etc.	1	ea	80	80	eng	65.00	5,200	200	200		0		0	5,400
2	Mob/demob	1	ea	16	16	hmt/eng	52.50	840	400	400	500	500		0	1,740
3	Survey crew	1	day		0			0		0		0	950	950	950
4	Site Orientation - 1 day	3	pers	8	24	op	28.74	690		0		0		0	690
5	Hazardous material technician	1	ea	64	64	hmt	40.00	2,560	100	100		0		0	2,660
6	Geologist	1	ea	64	64	eng	65.00	4,160		0	0	0		0	4,160
	Field Work														
1	Install monitoring wells, 25' ave,dp., 4" dia. S.S.	5	ea		0			0		0		0	5,000	25,000	25,000
2	Well drill waste disposal	15	drum		0			0		0		0	250	3,750	3,750
3	Sample analysis (Suite C)	5	ea		0			0		0		0	475	2,375	2,375
	Subtotal							**13,450**		**700**		**500**		**32,075**	**46,725**
	Taxes @ 6.5 %									46					46
	Subtotal														**46,770**
	Indirects @ 21.5%														10,056

** WBS T O T A L ** **$** **56,826**

Alternative 4, Extraction Wells Operations and Maintenance
LHAAP-67 Feasibility Study

WBS NO. :1.40.40.10.20

COMPANY NAME: SHAW E&I

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	LHAAP-67 (11 wells)														
	Total ---11 wells														
	Extraction Well O&M Annual costs														
1	Update safety, training ,waste, and	1	ea	24	24	eng	65.00	1,560	80	80		0		0	1,640
	health , plans, etc.														
2	Site Orentation,training, etc	1	lot	32	32	op	28.74	920		0		0		0	920
3	Mob/demob	1	ea	24	24	op	28.74	690	600	600	600	600		0	1,890
4	Install new filter socks	11	ea	24	264	pf	30.08	7,941	20	220	200	2,200		0	10,361
5	Leak test & clean 4" dia underground pipe, fittings,	1	lot	128	128	pf	30.08	3,850	3,000	3,000	1,600	1,600		0	8,450
	valves, pumps, etc --9600 lf.														
6	Extraction and booster pumps power usage	30482	kwh					0	0.093	2,835		0			2,835
	Subtotal							**14,961**		**6,735**		**4,400**		**0**	**26,096**
	Taxes @ 6.5 %									438					438
	Subtotal														**26,533**
	Indirects @ 21.5%														5,705
	Annual total														**32,238**
	O &M FOR 30 YEARS														**967,142**

**** WBS TOTAL **** **$ 967,142**

Alternative 4, Long-Term Monitoring
LHAAP-67 Feasibility Study

WBS NO. : 1.40.40.10.10

COMPANY NAME: SHAW E&I

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Monitoring of 10 wells														
	Year 1														
1	Establish initial database, licenses, coordinate well characterization & other well info, develop work plans, etc.	1	ea	300	300	eng	65.00	19,500	5,000	5,000		0	5,000	5,000	29,500
2	Collect and prepare samples quarterly (GW)	40	ea	16	640	tech	35.00	22,400	110	4,400	36	1,440		0	28,240
3	Sample analysis (Suite A)	40	ea		0			0		0		0	138	5,520	5,520
4	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**46,060**		**9,550**		**1,440**		**10,520**	**67,570**
	Taxes @ 6.5 %									621					621
	Subtotal														**68,191**
	Indirects @ 21.5%														14,661
	Year 1 Total														**$ 82,852**
	Year 2														
1	Collect and prepare samples quarterly (GW)	40	ea	16	640	tech	35.00	22,400	110	4,400	36	1,440		0	28,240
2	Sample analysis (Suite A)	40	ea		0			0		0		0	138	5,520	5,520
3	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
	Subtotal							**26,560**		**4,550**		**1,440**		**5,520**	**38,070**
	Taxes @ 6.5 %									296					296
	Subtotal														**38,366**
	Indirects @ 21.5%														8,249
	Year 2 Total														**$ 46,614**
	Years 3--4														
1	Collect and prepare samples annually (GW)	20	ea	16	320	tech	35.00	11,200	110	2,200	36	720		0	14,120
2	Sample analysis (Suite A)	20	ea		0			0		0		0	138	2,760	2,760
3	Annual report	2	ea	64	128	eng	65.00	8,320	150	300		0		0	8,620
	Subtotal							**19,520**		**2,500**		**720**		**2,760**	**25,500**
	Taxes @ 6.5 %									163					163
	Subtotal														**25,663**
	Indirects @ 21.5%														5,517
	Years 3--4 Total														**$ 31,180**

Alternative 4, Long-Term Monitoring
LHAAP-67 Feasibility Study

COMPANY NAME: SHAW E&I

WBS NO. : 1.40.40.10.10

PROJECT LOCATION: KARNACK, TEXAS

DATE: AUGUST 2005

Item				LABOR					MATERIAL		EQUIPMENT		SUBCONTRACT		
NO	DESCRIPTION	QTY	UNIT	UNIT MH	TOTAL MH	CRAFT	$/MH	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	$/UNIT	$ VALUE	TOTAL ($)
	Year 5														
1	Collect and prepare samples year 5 (GW)	10	ea	16	160	tech	35.00	5,600	110	1,100	36	360		0	7,060
2	Sample analysis (Suite A)	10	ea		0			0		0		0	138	1,380	1,380
3	Annual report	1	ea	64	64	eng	65.00	4,160	150	150		0		0	4,310
4	CERCLA 5-year review	1	ea	48	48	X-1	60.00	2,880		0		0	0	0	2,880
	Subtotal							**12,640**		**1,250**		**360**		**1,380**	**15,630**
	Taxes @ 6.5 %									81					81
	Subtotal														**15,711**
	Indirects @ 21.5%														3,378
	Year 5 Total														**$ 19,089**
	Years 6-9, 11-14, 16-19, 21-24, 26-29														
1	Collect and prepare samples annually (GW) for monitoring wells (10 wells)	200	ea	16	3200	tech	35.00	112,000	110	22,000	36	7,200		0	141,200
2	Sample analysis (Suite A) annually	200	ea		0			0		0		0	138	27,600	27,600
3	Annual report	20	ea	64	1280	eng	65.00	83,200	150	3,000		0		0	86,200
	Subtotal							**195,200**		**25,000**		**7,200**		**27,600**	**255,000**
	Taxes @ 6.5 %									1,625					1,625
	Subtotal														**256,625**
	Indirects @ 21.5%														55,174
	Years 6-9, 11-14, 16-19, 21-24, 26-29 Total														**$ 311,799**
	Years 10, 15, 20, 25, 30														
1	Collect and prepare samples annually (GW) for monitoring wells (10 wells)	50	ea	16	800	tech	35.00	28,000	110	5,500	36	1,800		0	35,300
2	Sample analysis (Suite A) every 5 years (GW)	50	ea		0			0		0		0	138	6,900	6,900
3	Annual report	5	ea	64	320	eng	65.00	20,800	150	750		0		0	21,550
4	CERCLA 5-year review	5	ea	48	240	X-1	60.00	14,400		0		0	0	0	14,400
	Subtotal							**63,200**		**6,250**		**1,800**		**6,900**	**78,150**
	Taxes @ 6.5 %									406					406
	Subtotal														**78,556**
	Indirects @ 21.5%														16,890
	Years 10, 15. 20, 25, 30 total														**$ 95,446**

**** WBS T O T A L **** **$ 586,980**