USAF Center for Engineering and the Environment
3300 Sidney Brooks
Brooks City-Base, Texas 78235-5112
Contract FA8903-08-D-8780, Task Order 0030

Focused Feasibility Study
(CDRL A001B)

Former USAF Plant PJKS
Waterton Canyon, Colorado

Revision 1

November 9, 2010

Shaw Environmental, Inc.

7604 Technology Way, Suite 300
Denver, Colorado 80237-3000

FOCUSED FEASIBILITY STUDY
(CDRL A001B)

FORMER AIR FORCE PLANT PJKS
WATERTON CANYON, COLORADO

REVISION 1

Prepared for:

USAF Center for Engineering and the Environment
3300 Sidney Brooks
Brooks City-Base, Texas 78235-5112
Contract F41624-03-D-8615, Task Order 0079

Prepared by:

Shaw Environmental, Inc.
7604 Technology Way, Suite 300
Denver, Colorado 80237-3000

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TABLE OF CONTENTS

Page

ABBREVIATIONS AND ACRONYMS

amsl	above mean sea level
ARD	Anaerobic Reductive Dechlorination
AFCEE	USAF Center for Engineering and the Environment
AM	Action Memorandum
ARAR	applicable or relevant and appropriate requirement
ASC	Aeronautical Systems Center
CBSG	Colorado Basic Standards for Groundwater
CCR	Code of Colorado Regulations
CDPHE	Colorado Department of Public Health and the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHWA	Colorado Hazardous Waste Act
CMS	corrective measures study
COC	contaminant of concern
CSA	contaminated soil areas
CSI	Combined Soils Additional Investigation
CSM	conceptual site model
CSSA	Central Support Storage Area
cy	cubic yards
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DHC	dehalococcoides ethenogenes
DO	dissolved oxygen
EE/CA	Engineering Evaluation/Cost Analysis
EEO	emulsified edible oil
EPA	U.S. Environmental Protection Agency
EPL	Engineering Propulsion Laboratory
FFS	Focused Feasibility Study
FSA	Fuel Storage area
ft	feet/foot
HRC®	Hydrogen Release Compound®
ICM	Interim Corrective Measures
IRP	Installation Restoration Program
LTM	long-term monitoring
LUC	Land Use Control
MCO	media cleanup objectives
MCS	media cleanup standards

ABBREVIATIONS AND ACRONYMS (cont'd)

µg/L	micrograms per liter
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NDMA	n-nitrosodimethylamine
NFA	no further action
nm	nanometers
NPL	National Priorities List
NSF	National Science Foundation
O&M	operation and maintenance
Order on Consent	State of Colorado Compliance Order on Consent, Number 98-10-08-01
OSWER	Office of Emergency and Remedial Response
OTL	Ordnance Testing Laboratory
OU	operable unit
ORP	oxidation reduction potential
PAH	polynuclear aromatic hydrocarbon
Parsons	Parsons Engineering Science, Inc.
PJKS	former USAF Plant PJKS
PPE	personal protective equipment
PQL	practical quantitation limit
PRB	permeable reactive barrier
RACER™	Remedial Action Cost Engineering and Requirements™
RAO	remedial action objective
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SCA	Systems and Components Area
Shaw	Shaw Environmental, Inc.
sq ft	square feet/foot
SRI	Supplemental RI
SWMU	solid waste management unit
T-8A	T-8A Pumphouse
TBC	to be considered
TCE	trichloroethene
TI	technical impracticability
TSCA	Toxic Substance Control Act
USACE	U.S. Army Corps of Engineers

ABBREVIATIONS AND ACRONYMS (cont'd)

USAF	United States Air Force
USC	United States Code
UV	ultraviolet
VC	vinyl chloride
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This Focused Feasibility Study (FFS) presents alternatives for remediation of groundwater contamination at the former United States Air Force (USAF) Plant PJKS (PJKS) in Waterton Canyon, Colorado (Figure 1).

Shaw Environmental, Inc. (Shaw) has prepared this FFS, which was performed in accordance with the program management principles and requirements of the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) listed in Title 40 of the Code of Federal Regulations (CFR) Part 300.430(a) (40 CFR 300.430(a)). The FFS uses a streamlined approach to reduce redundancy, facilitate rapid reviews, and accelerate cleanup decisions pursuant to the NCP (40 CFR 300.430(a)(1)(ii)(C)). The NCP is the federal government's blueprint for responding to both oil spills and hazardous substance releases.

A feasibility study is part of the remedy selection process under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and is comparable to a corrective measures study (CMS) under the Resource Conservation and Recovery Act (RCRA). CERCLA response activities are codified at 40 CFR Part 300 of the NCP and RCRA hazardous waste management activities are codified as an amendment to the Solid Waste Disposal Act. The environmental cleanup requirements of both CERCLA and RCRA apply to investigations and remedial actions at PJKS. The applicability of CERCLA and RCRA regulations to PJKS are outlined in the *Compliance Order on Consent* (Order on Consent) Number 98-10-08-01 (State of Colorado, 1998), which was signed on December 29, 1998.

The Order on Consent is an agreement between the USAF and the Colorado Department of Public Health and the Environment (CDPHE), Hazardous Materials and Waste Management Division. All state and federal corrective action regulations applicable to PJKS, including CERCLA, Defense Environmental Restoration Program (DERP), RCRA, NCP, and Colorado Hazardous Waste Act (CHWA), were merged in this agreement. The Order on Consent further provides for the integration of RCRA and CERCLA provisions as outlined in 42 United States Code (USC), Paragraph 6905b. The Order on Consent recognizes CDPHE as the lead regulatory agency for PJKS. Any site determination will comply with RCRA and State of Colorado regulations, such as the CHWA, and also is subject to the CERCLA model. In order to meet the intent of the CERCLA and RCRA corrective action program requirements, the CERCLA model for identifying and evaluating requirements is used in this report.

The work described in this document was performed under the USAF Center for Engineering and the Environment (AFCEE) Contract Number FA8903-08-D-8780. The Aeronautical Systems Center (ASC) at Wright-Patterson USAF Base, Ohio, manages environmental programs at PJKS, which are currently being implemented through AFCEE contracts.

1.1 OBJECTIVES OF THE FFS

The objectives of the FFS are to identify, develop, and evaluate remedial action alternatives for sites that, based on results from previous investigations, pose an unacceptable risk to human health and the environment and warrant action. Remedial Action Objectives (RAOs) have been established. RAOs are medium-specific remedial goals, or cleanup goals, for protecting human health and the environment. The RAOs values for groundwater were established according to the Colorado Basic Standards for Groundwater (CBSG).

The information presented in this FFS provides decision-makers with an assessment of alternatives, including their relative strengths and weaknesses, and the advantages/disadvantages of one alternative over another. The FFS supports an informed risk management decision for selecting the most appropriate means of meeting the RAOs. In addition, to satisfy U.S. Environmental Protection Agency (EPA) criteria, the selected remedial alternative must:

- Provide for overall protection of human health and the environment
- Comply with applicable or relevant and appropriate requirements (ARARs) of federal and state environmental laws (unless a specific ARAR is waived)
- Be cost-effective
- Use permanent solutions and innovative treatment technologies to the extent practicable

In consultation with the CDPHE, Hazardous Materials and Waste Management Division, and with input from the EPA and the public, the USAF will recommend an appropriate remedial alternative for groundwater at PJKS (as described in CERCLA Section 121) to CDPHE for selection. The proposed alternative will be presented in a Proposed Plan, which will be made available for public review. After responding to public comments on the Proposed Plan, the selected remedy will be formally documented in a Record of Decision (ROD) in accordance with the NCP (40 CFR 300.430(f)). The ROD is the formal, legal mechanism for documenting the remedy selection process and the analyses and policy determinations that support selection of the final remedy; the ROD will also serve as the Closure Plan for the CDPHE in accordance with 6 Code of Colorado Regulations (CCR) 1007-3, Part 264.112.

1.2 SCOPE OF THE FFS

The scope of this FFS has been streamlined to be practicable for the conditions present at PJKS and applies only to select contaminants of concern (COCs) that pose an unacceptable risk in the groundwater and warrant action at PJKS. This FFS was prepared in accordance with the suggested formats presented in the EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988b) and *RCRA Corrective Action Plan Document* (EPA, 1994). The FS Work Plan (Shaw, 2008b) provided the outline for this FFS.

Primary COCs in PJKS groundwater included trichloroethene (TCE) (and its daughter products) and n-nitrosodimethylamine (NDMA), a breakdown product of hydrazine rocket fuels. As a result, the scope of the FFS will be to develop and evaluate remedial alternatives that address only these compounds in the groundwater medium. The alternatives will be screened on the basis of the nine CERCLA criteria including:

- Overall Protection of Human Health and the Environment,
- Compliance with Potential ARARs,
- Long-term Effectiveness & Permanence,
- Reduction of Toxicity, Mobility, or Volume,
- Short-term Effectiveness,

- Implementability,
- Cost,
- State Acceptance, and
- Community Acceptance.

1.3 OPERABLE UNIT/SOLID WASTE MANAGEMENT UNIT STATUS SUMMARY

PJKS is located on approximately 464 acres near Waterton Canyon, in the Colorado Front Range in Jefferson County, Colorado. The site, which is approximately 20 miles southwest of downtown Denver, is completely surrounded by Lockheed Martin Corporation's 5,200-acre Waterton Canyon facility (Figure 1). In 1957, Lockheed Martin Corporation deeded the property to the USAF, which constructed a missile test site at PJKS. The USAF hired Lockheed Martin Corporation to be plant operator and prime tenant at PJKS. The PJKS facility was used from 1957 to 1968 as the main test facility for Titan rocket activities, including rocket assembly, engine testing, and research and development. Fuel development, purification, and testing of smaller engines and related apparatus also have taken place on site. The USAF owned the property until February 2001, when ownership was transferred to Lockheed Martin Corporation, the long-time operator of the facility. The USAF, however, maintains responsibility for the remediation of PJKS.

On November 21, 1989, the EPA listed PJKS on the National Priorities List (NPL). As part of the Order on Consent (State of Colorado, 1998), 56 Solid Waste Management Units (SWMUs), including three groundwater and 53 soil SWMUs, were identified as requiring evaluation. At the time, the individual SWMUs were called "Installation Restoration Program (IRP) sites" and were divided into six operable units (OUs). Primary COCs identified in PJKS soils included polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and pesticides. Primary COCs in PJKS groundwater included TCE and its daughter products and NDMA (a breakdown product of a hydrazine rocket fuels).

A number of investigations have been completed for the soil SWMUs; including a CERCLA remedial investigation/feasibility study (RI/FS) in the 1990's, and a comprehensive Supplemental RI (SRI) report in May 1999 (Parsons Engineering Science, Inc. [Parsons], 1998 and 1999). An early action was initiated at SWMUs 10 and 11 (Upper and Lower Volcano Areas) in 2000 and completed in 2001 that resulted in the removal of approximately 4,659 cubic yards of contaminated soil. The results of this and other previous investigations were used to support cleanup decisions of No Further Action (NFA), clean closed or closed with restrictions for 31 of the soil SWMUs. Twenty two SWMUs were identified as requiring additional soil characterization to address remaining data gaps.

Twenty of the 22 soil SWMUs requiring additional evaluation and investigation were grouped and termed "combined soils". These SWMUs include SWMUs 12, 13, 15 through 26, 29, and 31 through 35. These SWMUs were part of a *Combined Soils Additional Investigation* (CSI) *Report* (Shaw, 2005b). The CSI Report recommended closure (either restricted or unrestricted) for 13 soil SWMUs, and Interim Corrective Measures (ICMs) for seven soil SWMUs (12, 13, 15, 17, 22, 29, and 31) because these SWMUs posed an unacceptable risk to human health from exposure to the soil medium:

- Valve Shop Solvent Storage Area (SWMU 12),

- Valve Shop Process Water Drain (SWMU 13),
- Eastern End of the T-8 Drainage Flume (SWMU 15),
- D-2 Test Stand (SWMU 17),
- D-4 Test Stand (SWMU 22),
- Systems and Components Area (SCA) (SWMU 29), and
- Engineering Propulsion Laboratory (EPL) General Area (SWMU 31).

An *Interim Corrective Measures Study* (Shaw, 2005c) was completed to address the contaminated soils at the seven SWMUs. Three alternatives (No Action, Limited Cover and Land Use Controls (LUCs), and Limited Excavation and Offsite Disposal) were evaluated in the study. The selected ICM remedies included Limited Excavation, Offsite Disposal, and LUCs for four of the seven SWMUs (SWMU 13, 15, 17, and 22). The four SWMUs were approved for Restricted Closure due to all remaining soils being above residential standards but below industrial standards. The selected ICM remedy for the remaining SWMUs (SWMU 12, 29, and 31) included partial excavation with Limited Cover and LUCs. In 2005, a total of 2,915 cy of contaminated soil was excavated from the various SWMUs and disposed at a permitted RCRA Subtitle D landfill. The two SWMUs were approved for Restricted Closure with LUCs and Limited Covers because all remaining soils are above industrial standards.

The remaining two soil SWMUs (9 and 14) were addressed under a separate investigation. The D-1 Landfill (SWMU 9) is located in the south-central portion of PJKS, immediately north of the D-1 Test Stand. The T-31 Chemical Treatment Facility (SWMU 14) is located immediately north of the D-1 Landfill. In 2003, an *Evaluation of Alternatives* report was prepared to evaluate two potential remedies for the D-1 Landfill and the T-31 Chemical Treatment Facility (Shaw, 2003c). The two potential remedies (excavation and offsite disposal and installation of a landfill cover system) were determined to be technically feasible based on the additional investigation results. Based on the evaluation, excavation and offsite disposal was selected as the most effective and preferred alternative. Excavation activities began in September 2008 and resulted in 47,090 cy of non-hazardous waste, 600 cy of Toxic Substance Control Act (TSCA) waste, 306 cy of concrete, and 4,835 tons of scrap iron being removed from the area (Shaw, 2009b). The two SWMUs were approved for Unrestricted Closure because all remaining soils are below residential standards.

Previous investigations and ICMs for soil SWMUs at PJKS have resulted in recommendations for Unrestricted Closure, Restricted Closure with LUCs, or Restricted Closure with LUCs and Limited Cover. Results for each soil SWMU and corresponding recommendations are summarized in Table 1. Closure letters are included as Appendix A.

Groundwater contamination at PJKS resulted from activities associated with the development of rocket launch equipment, engine testing, and/or fuels development, purification, and testing. Past operations resulted in three groundwater plumes moving between three different aquifers. The three groundwater SWMUs are identified as:

- SWMW 1 East Fork Brush Creek Groundwater Plume
- SWMU 2 West Fork Brush Creek Groundwater Plume
- SWMU 3 Lariat Gulch Groundwater Plume

Numerous investigations have been completed at the groundwater SWMUs between 1986 and 2009. Primary investigations included the RI/FS, the SRI completed in 1999 (Parsons, 1998 and 1999), *Supplemental Remedial Investigation Addendum 1, OU4 - Lariat Gulch Groundwater Plume* (Stone & Webster 2001), *Supplemental Remedial Investigation Addendum, OU5 - Brush Creek Groundwater Plume* (Shaw 2003a), *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b), *Groundwater Treatment Studies Report, N-Nitrosodimethylamine with Trichloroethene* (Shaw, 2008a), and the *2009 Annual Groundwater Monitoring Report* (Shaw, 2010c). The results of these reports were used to determine the location of seven groundwater contaminant source areas (Figure 2), the lateral extent of the groundwater contaminant plumes, and the effectiveness of in-situ bioremediation on TCE and NDMA.

Because contamination from the three SWMUs are similar and have been identified in distinct source areas defined by geographic location, the three SWMUs are characterized as one for purposes of remedial alternative analysis in this FFS. Additional details on the source areas as they relate to the SWMUs are provided in Section 2.2. TCE is the primary COC; therefore its distribution in the groundwater system(s) generally approximates the greatest extent of contamination. The data resulting from the different investigations indicate there are seven bedrock groundwater source areas that have continually exhibited the maximum sustained concentrations of TCE and NDMA. The seven bedrock groundwater source areas all contribute to the offsite migration of three groundwater plumes (see Figure 2). The source areas identified are:

- the D-1 area [TCE and NDMA source area],
- the D-4 Fuel Storage area (FSA) [TCE source area],
- the EPL area [TCE source area],
- the SCA [TCE and NDMA source area],
- the Central Support Storage area (CSSA) [TCE and NDMA source area],
- the Ordnance Testing Laboratory (OTL) area [TCE source area],
- and the T-8A Pump House (T-8A) area [TCE and NDMA source area].

Various pilot studies and bench scale tests have been completed at PJKS. Details are provided in Section 5.0. The pilot studies resulted in the biological degradation of TCE in groundwater, including the production of all of the byproducts and the end-product, ethene. The results indicated that the source areas for groundwater are amenable to anaerobic bioremediation via in-situ injection techniques. The Pilot Study evaluations of the NDMA anaerobic degradation did not show any evidence of a reduction in groundwater concentrations. Concentrations of NDMA in groundwater remained constant throughout the course of the pilot studies.

Preliminary RAOs were established for the entire groundwater medium at PJKS at a meeting among USAF, EPA, and CDPHE on December 7, 2005. Additional refinement of the RAOs was presented in letters provided by CDPHE and EPA on January 25, 2006 and February 8, 2006 (see Appendix B). A presumptive remedy approach was then used to develop a focused engineering evaluation/cost analysis (EE/CA) based on the pilot test results. The focused EE/CA used a streamlining approach (plug-in approach) to implement the presumptive remedy at multiple locations at PJKS. The plug-in approach is a method of repetitively implementing a removal action for multiple groundwater source areas that are physically similar and have comparable contaminants. This approach eliminates the need to perform separate EE/CAs at individual source areas where the removal action for contaminants in groundwater will use the same technology. In agreement with CDPHE and EPA, this also reduces the need for multiple Action Memorandums (AM). Based on the results of the focused EE/CA and AM (Shaw, 2005d and 2006a), in-situ bioremediation, in the form of anaerobic reductive dechlorination (ARD), coupled with bioaugmentation where warranted, was implemented as an ICM at the D-1, D-4, EPL, SCA, CSSA, OTL, and T-8A source areas at PJKS (Shaw, 2009a). Additional information on the ICMs is provided in Section 5.5. Shaw is continuing ongoing performance monitoring and operations and maintenance (O&M) work on these ICM systems (Shaw, 2010a). Performance monitoring results indicate that TCE is either degrading at all seven source areas, or breakdown products of TCE have been observed at the source areas indicating the breakdown of TCE is staring to occur.

1.4 REPORT ORGANIZATION

The FFS report consists of 11 sections:

- **Section 1** introduces the background of the FFS, states its objectives and scope, and provides a summary of activities at the OUs/SWMUs.
- **Section 2** summarizes current conditions of the groundwater at PJKS, including the potentiometric surface, distribution of COCs, temporal changes in COCs, and a conceptual site model (CSM).
- **Section 3** identifies ARARs
- **Section 4** presents the RAOs intended to provide adequate protection of human health and the environment.
- **Section 5** discusses the results of various pilot studies, bench scale studies, and ICMs that have been completed at the site.
- **Section 6** presents a technical impracticability (TI) evaluation of ARARs, the TI zone, CSM, and restoration potential at the site.
- **Section 7** identifies general response actions that address the RAOs, identifies and screens remedial technologies and process options, and introduces the identification and more detailed screening of remedial action alternatives for groundwater.
- **Section 8** presents a detailed analysis of the potential remedial actions remaining after the screening process using seven of the nine evaluation criteria listed in 40 CFR 300.430(e)(9)(iii)
- **Section 9** presents a comparative analysis of the remedial alternatives
- **Section 10** presents the recommended alternative for groundwater at PJKS
- **Section 11** lists the references used in the preparation of this document

2.0 CURRENT CONDITIONS

One of the streamlining measures used in this FFS involves integrating the results of previously conducted remedial/site investigations. Previous remedial investigations have been used to evaluate site conditions that may or may not limit the restoration potential of PJKS groundwater. Semi-annual site-wide groundwater monitoring, as well as quarterly ICM monitoring, have been used to assess the current hydrogeological conditions and the effectiveness of the ICMs for the treatment of groundwater (Shaw, 2010b and 2010c).

2.1 POTENTIOMETRIC SURFACE

Three categories of geologic media produce sufficient water to be considered aquifers at PJKS; groundwater is present in all or part of each of these three geologic formations:

- The Quaternary age alluvium, which is composed of discontinuous layers of unconsolidated clay, silt, sand, gravel, and cobbles; these layers range up to 30 feet (ft) in thickness.
- The Fountain Formation, which is composed of sandstone interbedded with siltstone and claystone. The formation strikes approximately north 30 degrees west and dips to the northeast approximately 40 to 60 degrees. The Fountain Formation is found predominantly along the east side of PJKS.
- The Precambrian Formation, which is fractured crystalline rock underlying both the Quaternary age alluvium and Fountain Formation along the west side of PJKS.

Groundwater sampling has been ongoing at PJKS since 1985. For the past several years, groundwater samples have been collected semi-annually. The most current data available from the spring and fall 2009 groundwater sample and water level measurement results, collected in accordance with the *Interim Groundwater Monitoring Plan* (Stone & Webster, 2002a), are discussed in this FFS. These results, as well as a brief discussion of the quarterly ICM Performance Monitoring, are also included in the *2009 Annual Groundwater Report* (Shaw, 2010c).

Table 2 includes the groundwater elevations measured during the spring and fall 2009 program events. Brief discussions of groundwater elevations collected from the three PJKS aquifers are provided in the following sections. Because the spring 2009 program event included only five wells, potentiometric maps were created for only the fall 2009 program event data.

2.1.1 **Alluvial Aquifer**

Groundwater in the alluvium is characterized by unconfined water table conditions within the saturated zone(s) of that formation. The direction of groundwater flow in the alluvium is controlled by the underlying bedrock topography. In general, groundwater in the alluvial aquifer flows from west to east across the PJKS property. However, in the northeastern portion of the property the groundwater flow is from southeast to northwest. During the spring 2009 program event, the depth to groundwater was not measured in any monitoring well screened in the alluvium. Time plots of the recorded elevations indicate that groundwater elevations in the alluvial aquifer have remained consistent over the past two decades. Potentiometric maps of 2009 fall alluvial groundwater elevations are shown in Figure 3.

2.1.2 Fountain Formation Aquifer

In the Fountain Formation, the interbedded sandstone layers can behave as independent aquifers, resulting in the Fountain Formation being an aquifer system rather than one aquifer. Both confined and unconfined conditions are present in the Fountain Formation. The direction of groundwater flow in the Fountain Formation is consistent with that of the alluvium. The spring and fall 2009 monitoring events showed an average spring-to-fall groundwater depression of approximately one foot (Table 2), which is consistent with the expected seasonal variations and is within the range of previous data. Time plots of the recorded elevations also show that groundwater elevations in the Fountain Formation have remained consistent over the past two decades. Potentiometric maps of fall 2009 Fountain Formation groundwater elevations are shown in Figure 4.

2.1.3 Precambrian Aquifer

Groundwater flow in the Precambrian Formation is characterized as fractured flow. Both confined and unconfined conditions are present in the Precambrian Formation. Depending on the stratigraphic relationship of these hydrogeologic units at any specific location within the PJKS area, groundwater flows between one or more of these units. The general direction of groundwater flow in the Precambrian aquifer is from northwest to southeast across the site. The 2009 groundwater monitoring data showed that, on average, groundwater elevations in the fall were approximately 7.54 ft (Table 2) lower than in the spring. This variation is also within the expected seasonal variation and is consistent with historical levels. In addition, time plots show that groundwater elevations in the Precambrian Formation have remained consistent over the past two decades. Potentiometric maps of fall 2009 Precambrian bedrock groundwater elevations are shown on Figure 5.

2.2 CONTAMINANT DISTRIBUTION IN SWMUs

As part of the ongoing groundwater semi-annual sampling program, groundwater samples were collected from the East Fork Brush Creek SWMU, the West Fork of Brush Creek SWMU, and the Lariat Gulch SMWU in the spring and fall of 2009. The total number of monitoring wells in the 2009 sampling program was 61. However, because of the large amount of historical data and the overall stability of the plume, only five of these wells are sampled in the spring and no contamination plume maps were prepared for this program event. In the fall, all 61 wells were sampled. The samples were submitted for volatile organic compound (VOC) and NDMA analyses. The *2009 Annual Groundwater Report* (Shaw, 2010c) summarizes the analytical results from the 2009 sampling.

2.2.1 TCE Distribution in SWMUs

Because TCE is the primary COC, its distribution in the groundwater system(s) is generally used to approximate the greatest extent of contamination. Plume maps of TCE contaminant concentrations were completed from the fall 2009 sampling results for the Alluvial, Fountain Formation and Precambrian Aquifers as shown in Figures 6 thru 8.

SWMU No. 1 – East Fork of Brush Creek. Current and historical data indicate that TCE contamination in the East Fork Brush Creek SWMU originates from the D-1, D-4, EPL, SCA, CSSA, and T-8A source areas. In the spring of 2009, groundwater samples were collected from three East Fork Brush Creek SWMU monitoring wells located within and downgradient of these source areas. The VOC results from one well exceeded the CBSGs; TCE results in this one well also exceeded CBSGs. In the fall of 2009, 28 monitoring wells were sampled. Samples from 21 wells had VOC concentrations exceeding the corresponding CBSG values. TCE results in all 21 of these wells also exceeded CBSGs. Historical data shows that the TCE concentrations in these wells have either remained consistent, or have steadily decreased since monitoring began in the early 1990s. Specifically, TCE concentrations in the most downgradient alluvial well (5-M04) have been consistent over time, and were below CBSGs in 2009. The data indicates that the TCE plume at PJKS is stable and TCE contamination in the East Fork Brush Creek SWMU is not migrating further downgradient from the source areas.

SWMU No. 2 – West Fork of Brush Creek. Current and historical data indicate that TCE contamination in the West Fork Brush Creek SWMU originates from the D-1, T-8A, and OTL source areas. Groundwater samples were collected from 13 monitoring wells within and downgradient of these source areas in the fall of 2009. No West Fork Brush Creek SWMU monitoring well samples were analyzed for VOCs during the spring 2009 program event. VOCs were reported in eight of the samples at concentrations exceeding the corresponding CBSG values. TCE concentrations in all eight wells also exceeded CBSGs. Historical data shows that the TCE concentrations in these wells have remained consistent, or have steadily decreased since monitoring began in the early 1990s. Specifically, TCE concentrations in the most downgradient alluvial well (5-M24), an OTL alluvial source area well, have been consistent over time and were below CBSGs in 2009. The data indicates that the TCE plume at PJKS is stable and TCE contamination in the West Fork Brush Creek SWMU is not migrating further downgradient from the source areas.

SWMU No. 3 – Lariat Gulch. Current and historical data indicate that TCE contamination in the Lariat Gulch SWMU originates from the D-4, EPL, SCA, and CSSA source areas. One Lariat Gulch monitoring well sample was analyzed for VOCs in the spring of 2009, which did not have a concentration that exceeded the corresponding CBSG values. Sixteen Lariat Gulch monitoring well samples were analyzed for VOCs in the fall of 2009, which were reported in nine of the samples at concentrations exceeding the corresponding CBSG values. All nine of these samples had TCE concentrations exceeding CBSGs. Historical data show that the TCE concentrations in these wells have remained consistent, or have steadily decreased since monitoring began in the early 1990s. Specifically, TCE concentrations in downgradient alluvial well LGMW-011A and bedrock well GM91B have been consistent over time, and were below CBSGs in 2009. The data indicates that the TCE plume at PJKS is stable and TCE contamination in the Lariat Gulch SWMU is not migrating further downgradient from the source areas.

2.2.2 NDMA Distribution in SWMUs

As stated in CDPHE Regulation No. 41 (CDPHE, 2009), "whenever the practical quantitation limit or (PQL) for a pollutant is higher (less stringent) than a standard listed … the PQL shall be used in regulation specific activities." The value 0.7 micrograms per liter (µg/L), which is the PQL for EPA Method 8070A, has historically been used as the CBSG value for NDMA results. However, on September 25, 2007 CPDHE approved a low-level NDMA method, which has a PQL of 0.05 µg/L; therefore, the CBSG value for NDMA is now 0.05 µg/L.

The *2009 Annual Groundwater Report* (Shaw, 2010c) summarizes the analytical results from the 2009 sampling. A NDMA plume map was prepared for the fall 2009 program event (which has a larger monitoring well network sampled as compared to the spring 2009 event) for all three aquifers as shown on Figure 9.

SWMU No. 1 – East Fork of Brush Creek. Current and historical data indicate that NDMA contamination in the East Fork Brush Creek SWMU originates from the D-1, SCA, CSSA, and T-8A source areas. Groundwater samples were collected from one East Fork Brush Creek SWMU in the spring of 2009 and analyzed for NDMA. This sample reported NDMA results exceeding CBSGs. Fifteen East Fork Brush Creek SWMU monitoring well samples were analyzed for NDMA in the fall of 2009. Exceedances of the CBSG for NDMA were reported in samples from seven wells (Figure 9). Historical data show that the NDMA concentrations in these wells have remained consistent since monitoring began in the early 1990s. Specifically, NDMA concentrations in downgradient alluvial well III-2-M5 have been consistent over time, and were below CBSGs in 2009. The data indicates that the NDMA plume at PJKS is stable and NDMA contamination in the East Fork Brush Creek SWMU is not migrating further downgradient from the source areas.

SWMU No. 2 – West Fork of Brush Creek. Current and historical data indicate that NDMA contamination in the West Fork Brush Creek SWMU originates from the D-1 and T-8A source areas. No West Fork Brush Creek SWMU monitoring well samples were analyzed for NDMA during the spring 2009 program event. Six West Fork Brush Creek SWMU monitoring well samples were analyzed for NDMA during the fall of 2009. One sample exceeded the CBSG for NDMA for the fall 2009 program event (Figure 9). Historical data show that the 2009 data collected are consistent with historical NDMA concentrations reported. The data indicates that the NDMA plume at PJKS is stable and NDMA contamination in the West Fork Brush Creek SWMU is not migrating further downgradient from the source areas.

SWMU No. 3 – Lariat Gulch. Current and historical data indicate that NDMA contamination in the Lariat Gulch SWMU originates from the SCA and CSSA source areas. One Lariat Gulch monitoring well sample was analyzed for NDMA during the spring of 2009. The sample did not exceed the CBSG for NDMA during the spring 2009 program event. Six Lariat Gulch monitoring well samples were analyzed for NDMA during the fall 2009 sampling, which was reported in two samples at concentrations exceeding the CBSG concentration (Figure 9). Historical data shows that the NDMA concentrations in these wells have remained consistent since monitoring began in the mid 1990s. Specifically, NDMA concentrations in downgradient bedrock well GM91B have been consistent over time, and were below CBSGs in 2009. The data indicate that the NDMA plume at PJKS is stable and NDMA contamination in the Lariat Gulch SWMU is not migrating further downgradient from the source areas.

2.3 TEMPORAL CHANGES RESULTING FROM ICMs

The ongoing semi-annual sampling program was implemented to monitor the distribution of TCE and NDMA in the groundwater SWMUs at PJKS. Recently, quarterly sampling has also been conducted at PJKS to monitor the effectiveness of ICMs, primarily in-situ bioremediation, implemented at the seven bedrock source areas at PJKS. Results of previous pilot studies conducted at PJKS indicate that ARD is an effective treatment for TCE contamination at PJKS. Specifically, study results have shown that injecting sodium lactate into site wells is an effective means of enhancing the biodegradation of TCE. Implementation of the ICMs began in 2006 at the D-1 and D-

4 source areas. ICMs were implemented at the EPL and SCA source areas in 2007; and at the remaining source areas in 2008. The ICMs are discussed in more detail in Section 5.5.

The most recent results of the ICM quarterly performance monitoring at PJKS are reported in the *Technical Memorandum, Groundwater Interim Corrective Measure Performance Monitoring Report, Report #7* (Shaw, 2010b). Quarterly performance monitoring wells include the wells into which lactate is injected, as well as adjacent monitoring wells. In some cases the same wells are monitored as part of both the semi-annual monitoring and the quarterly performance monitoring. However, the performance monitoring wells are selected based on the ICM locations and the source areas and many of the wells have not previously been sampled as part of the ongoing groundwater monitoring at PJKS. Therefore, while the results of semi-annual groundwater monitoring at PJKS show that TCE concentrations across the site have stayed consistent or have slightly decreased, the results of the performance monitoring show more dramatic decreases in TCE concentrations, particularly in the D-1, D-4, and EPL source areas as a result of the ICM treatments. The monitoring wells that are part of the ICMs and performance monitoring are shown on Figures 10 and 11. The effectiveness of the ICMs is measured by monitoring the decrease in TCE concentrations, the concentrations of TCE daughter products, and the dissolved oxygen (DO) and oxidation reduction potential (ORP) in the source areas.

2.4 CONCEPTUAL SITE MODEL

Groundwater contamination at PJKS has resulted from activities associated with the development of rocket launch equipment, engine testing, and/or fuels development, purification, and testing. Numerous studies of PJKS groundwater composition and fate and transport of contaminants have contributed to development of a CSM of conditions at PJKS. The CSM, which is graphically illustrated in Figures 12 and 13, is a summary of site conditions that identifies: the type and location of sources of contamination; and how and where people, plants, or animals may be exposed to the contamination. A more detailed explanation of the CSM can be found in Section 6.3.

2.4.1 **Type of Contamination**

The type of groundwater contamination at PJKS was determined by evaluating several years of groundwater monitoring data. TCE, which emerged as the most persistent and extensive PJKS groundwater contaminant, is the primary COC at PJKS. NDMA is also a COC, although not as widely dispersed as TCE.

2.4.2 **Sources of Contamination**

Because TCE is the primary COC, and its distribution in the groundwater system(s) generally approximates the greatest extent of contamination, TCE data were initially used to generate contaminant distribution maps. The locations of sources of PJKS contamination were developed from these distribution maps of TCE, which were plotted in each of the three groundwater aquifers (e.g. the Alluvial, Fountain, and Precambrian). The maps were overlain on each other to observe the relationship(s) between the distributions of contaminants within the hydrogeologic units. Seven bedrock areas were identified as the apparent sources of the three groundwater SWMUs (Figure 14). Generally, the source areas are located near specific operational locations within PJKS and the CSM treats the seven areas as the only sources of groundwater contamination at PJKS. The source areas are identified as the D-1, D-4, EPL, SCA, CSSA, OTL, and T-8A source areas (Figure 2). All seven groundwater sources areas are TCE source areas. Four of these locations (SCA, D-1, T-8A, and CSSA) are also NDMA source areas. As illustrated on Figure 14, the D-1, D-4, EPL, SCA, CSSA, and T-8A source areas contribute to TCE and NDMA concentrations in the East Fork Brush Creek SWMU (SWMU 1); the D-1, EPL OTL, and T-8A source areas contribute to TCE and NDMA concentrations in the West Fork Brush Creek SWMU (SWMU 2); and the D-4, EPL, SCA, and CSSA source areas contribute to TCE and NDMA concentrations in the Lariat Gulch SWMU (SWMU 3). Because the seven source areas are sufficiently similar, this CSM is applied to all plumes.

2.4.3 Release Mechanisms

Operational facilities at PJKS were frequently located on bedrock ridges or topographically elevated areas. Contaminated process water infiltrated into the ground surface and subsequently into near surface bedrock. Movement through the bedrock continued downward and laterally. The steep topographical relief at PJKS results in groundwater from deep bedrock migrating laterally into shallow alluvial drainage channels where attenuation increased as a result of additional alluvial subsurface drainage flow, precipitation infiltration, and higher lateral transport rates. No “significant” levels of groundwater contamination have been found in surface water exceeding the maximum contamination levels for drinking water.

2.4.4 Transport/Contact Media

Potential transport pathways at PJKS, and the media within which they occur, are bedrock groundwater, alluvial groundwater, and surface water (see Figure 12).

2.4.5 Human Receptors and Potential Exposure Route

PJKS and the surrounding Lockheed Martin properties are currently industrial sites with no residential inhabitants. Therefore, under current and reasonable future conditions, human receptors for the groundwater medium associated with contaminants from PJKS would be commercial/industrial workers. Because future land use is indefinitely restricted at PJKS and the surrounding property, commercial/industrial workers are also identified as future receptors.

As presented in Figure 13, the following potential routes of exposure have been identified for current and future receptors at PJKS:

- Ingestion of groundwater,
- Inhalation of TCE vapors from groundwater, and
- Dermal contact with groundwater.

2.4.5.1 Ingestion of Groundwater

Ingestion of groundwater and dermal contact with groundwater are unlikely scenarios based on the current use of the property. Currently, there is no complete pathway for ingestion of groundwater because groundwater in the area is not a drinking water source.

2.4.5.2 Inhalation

TCE and its breakdown/daughter products 1,2-dichloroethene (1,2-DCE) and VC evaporate readily into the air (EPA, 2002). One of the known pathways of human exposure to these constituents is via evaporation from contaminated groundwater into the pore spaces of soil above the groundwater and then into the air above the ground surface via continued evaporation. If these chemicals reach the ground surface in an open area, the contaminants dissipate rapidly in the large volume of outdoor air and are not a concern to human health or the environment. If the constituents surface beneath an inhabited building, there is a potential for them to migrate through cracks or gaps in the buildings floor and contaminate the breathing air of the buildings inhabitants. The potential for PJKS workers to be exposed to VOCs in the PJKS groundwater is considered to be negligible for the following reasons:

Bedrock Groundwater
There are inhabited buildings located above VOC-contaminated groundwater in the Fountain Formation in the SCA and the EPL areas. However, the potential for migration of VOCs from Fountain Formation groundwater is very low because the groundwater primarily flows through small fractures in the rock that are located inches to several feet apart. As a result, the available area for the VOCs to evaporate from the groundwater surface is very small so little evaporation occurs.

Alluvial Groundwater
The only inhabited building on PJKS situated above saturated alluvium contaminated with VOCs is the Missile Storage Building (Building T-42) located near the CSSA. The concentration of TCE in the alluvial groundwater beneath the Missile Storage Building is approximately 16 µg/L, which CDPHE has determined through years of research to be too low to cause indoor air contamination at levels considered a threat to human health at a residential/unrestricted use level. In addition, the Missile Storage Building is not inhabited by workers on a regular basis.

2.4.5.3 Dermal Contact

There is a slight potential for dermal contact with groundwater during construction activities; however, this potential is negligible. Depth to groundwater is typically greater that the depth of construction activities. Lockheed Martin maintains a current ‘black zone map’ that is used to indicate areas where digging is not appropriate. This map was created for worker safety and is an early step in the planning of all construction projects on site. The black zone map restricts digging activities greater than 25 ft below final ground surface, monitoring personal protective equipment (PPE), and logging worker hours (Shaw, 2010a).

2.4.6 ECOLOGICAL RECEPTORS AND POTENTIAL EXPOSURE ROUTES

Contaminants of potential concern in groundwater at the site are inaccessible to terrestrial receptors and there are no completed pathways for aquatic receptors.

3.0 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CERCLA §121(d) specifies that remedial alternatives must achieve overall protection of human health and the environment, and must be in compliance with ARARs. ARARs are identified in the FFS as shown in Tables 3 thru 5, and at other stages in the remedy selection process. Regulations codified in the NCP [40 CFR 300.430(f)(1)(ii)(B)] govern the identification of ARARs and require compliance with ARARs throughout the CERCLA remediation process. Under certain limited circumstances, ARARs for onsite remedial actions may be waived [Section §121(e) of CERCLA].

3.1 DEFINITION OF ARARs

Any regulation, standard, requirement, criterion, or limitation under any federal or state law may be either applicable or relevant and appropriate to remedial action. Criteria, advisories, and guidelines that are not law may be used to provide guidance in the absence of ARARs or when ARARs are not sufficient to protect human health and the environment. These criteria, advisories, and guidelines are in the to be considered (TBC) category.

As defined, federal and state requirements must be considered for identification of site-specific ARARs. Federal and state requirements include ARARs that are:

- Chemical-specific (i.e., govern the level or extent of site remediation in relation to a specific constituent),
- Location-specific (i.e., pertain to existing site features), and
- Action-specific (i.e., pertain to proposed site remedies and govern implementation of the selected site remedy).

3.2 IDENTIFICATION OF ARARs

Identification of ARARs is performed on a site-specific basis and involves a two-part analysis: first, a determination of whether a given requirement is applicable; then, if it is not applicable, a determination of whether it is relevant and appropriate (EPA, 1988a).

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 PJKS. To be applicable, a requirement must directly and fully address a CERCLA activity.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that may not be directly applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at any site, but that address problems or situations sufficiently similar to those encountered at the site so that their use is well-suited. To determine whether a requirement is relevant and appropriate, a comparison must be made of the characteristics of the remedial action, the hazardous substances present, and the physical circumstances of PJKS to those addressed in the statutory or regulatory requirement. In some cases, a requirement may be relevant, but not appropriate. It may also be the case that only part of a requirement will be considered relevant and appropriate in a given case. When the determination indicates that a requirement is both relevant and appropriate, such a requirement must be complied with to the same degree as if it were applicable (EPA, 1988a).

The identification of ARARs is an iterative process to be considered throughout the remedial response. Therefore, the list of identified requirements and their relevance may change as more information is obtained, the preferred alternative is chosen, and the design and approach to remediation is refined.

3.2.1 **Chemical-Specific ARARs**

Chemical-specific ARARs are usually promulgated health-or risk-based numerical values or methodologies used to determine acceptable concentrations of chemicals that may be found in, or discharged to, the environment. These ARARs govern the extent of site remediation by providing cleanup levels or a basis for calculating cleanup levels. Potential chemical-specific ARARs that relate to the COCs and media of concern at PJKS are identified in Table 3.

3.2.2 **Location-Specific ARARs**

Location-specific ARARs restrict actions or contaminant concentrations in certain environmentally sensitive areas (e.g., within or adjacent to wetlands, floodplains, existing landfills, disposal areas, and places of historical or archaeological significance). Potential location-specific ARARs that relate to PJKS are identified in Table 4.

3.2.3 **Action-Specific ARARs**

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. After remedial alternatives are developed, action-specific ARARs pertaining to proposed site remedies provide a basis for assessing the feasibility and effectiveness of the remedies. The potential action-specific ARARs are identified in Table 5.

3.2.4 **To be Considered Category**

The TBC category represents non-promulgated advisories, agreements, or guidance issued by the federal or state government, which do not have the status of potential ARARs. If there are no specific ARARs for a chemical or a site condition, or if existing ARARs are not sufficiently protective, then guidance or advisory criteria can be used in the development of cleanup goals and the design of remedial actions. Three categories of TBC information are (1) health effects information; (2) technical information on how to perform or evaluate site investigations or response actions; and (3) regulatory policy or proposed regulations.

Five preliminary TBCs have been identified for consideration in the FFS: CDPHE's *Corrective Action Guidance Document* (CDPHE, 2002); the *Compliance Order on Consent in the Matter of Air Force Plant PJKS Site, No. 98-10-08-01* (State of Colorado, 1998); the January 25, 2010 letter from CDPHE and EPA to ASC clarifying the path forward regarding the remaining obligations to remediate contaminated groundwater at PJKS (CDPHE, 2010); the Memorandum of Agreement between Lockheed Martin and the USAF dated March 15, 2010 (Lockheed Martin, 2010); and the

May 19, 2008 letter from CDPHE to ASC requiring the use of a modification to the approved NDMA analytical method for PJKS groundwater (CDPHE, 2008).

Corrective Action Guidance Document. The CDPHE's *Corrective Action Guidance Document* provides an overall implementation framework and model scopes of work for site characterization, interim actions, evaluation of remedial alternatives and remedy implementations (CDPHE, 2002).

Compliance Order on Consent. The environmental cleanup requirements of both CERCLA and RCRA apply to investigations and remedial actions at PJKS. The applicability of CERCLA and RCRA regulations to PJKS are outlined in the Order on Consent Number 98-10-08-01 (State of Colorado, 1998), which was signed on December 29, 1998. The Order on Consent is an agreement between the USAF and the CDPHE, Hazardous Materials and Waste Management Division. All state and federal corrective action regulations applicable to PJKS, including CERCLA, DERP, RCRA, NCP, and CHWA, were merged in this agreement. The Order on Consent recognizes CDPHE as the lead regulatory agency for PJKS.

Clarification Letter. On January 25, 2010 CDPHE and EPA issued a letter to ASC to establish the path forward with regard to the remaining obligations to remediate the contaminated groundwater at PJKS. The final paragraph of this letter states that if Lockheed Martin renders a decision to allow the continuing migration of PJKS contaminated alluvial groundwater into its property that the FFS no longer needs to contain a proposal to halt the continued flow of TCE and NDMA contaminated groundwater beyond the PJKS boundary or to actively treat TCE and NDMA contaminated groundwater on Lockheed Martin property.

Memorandum of Agreement. The USAF and Lockheed Martin reached a Memorandum of Agreement dated March 15, 2010 (Lockheed Martin, 2010). In this memorandum, Lockheed Martin agrees to execute an Environmental Covenant on the portion of the Lockheed Martin property where TCE and NDMA contaminated groundwater exists and is sourced from PJKS. This agreement fulfills the conditions of the clarification letter above for Lockheed Martin to render a decision to allow the continuing migration of PJKS contaminated alluvial groundwater into its property.

NDMA Analytical Requirement Letter. On May 19, 2008 CDPHE issued a letter to ASC requiring the use of a proprietary modification to the approved existing NDMA analysis with lower method detection limits and PQLs.

4.0 REMEDIAL ACTION OBJECTIVES

To be efficient and avoid duplication, the Order on Consent requires the USAF meet the requirements of CERCLA and RCRA for all corrective actions at the site. CERCLA RAOs are medium-specific remedial goals for protecting human health and the environment. RAOs include the COCs, exposure scenarios, and the corresponding acceptable chemical concentration [preliminary remediation goals (PRGs)] for each exposure route. RAOs recognize that protection may be achieved by reducing exposure as well as by reducing chemical concentrations. The corresponding RCRA media cleanup objectives (MCOs) include the media cleanup standards (MCSs), points of compliance, and cleanup time frames. The MCSs are similar to the PRG included in the development of CERCLA RAOs. Points of compliance and cleanup time frames are additional criteria.

The primary goals of both CERCLA and RCRA programs are to: 1) protect human health and the environment; 2) include the public in the remedial decision-making process; and 3) effectively attain cleanup standards. Under CERCLA, ARARs are used to establish the acceptable PRGs for the RAOs. For RCRA, the MCSs are usually set using drinking water or background levels for the MCOs.

4.1 BACKGROUND FOR DEVELOPMENT OF RAOS

The two groundwater COCs that pose an unacceptable risk are TCE and NDMA. The data necessary to prepare the specific groundwater medium RAOs using the CERCLA/RCRA criteria/standards described above for PJKS are available from the numerous investigations, treatability studies, and ICMs that have been completed or are in progress. The CSM for the groundwater medium at PJKS indicates two major groundwater components that require remedial action/corrective action: bedrock source areas and alluvial groundwater contamination.

Bedrock Source Area Groundwater

The extensive soil contaminant investigations that have been conducted throughout PJKS have shown that there are no longer any “traditional” contaminant source areas within the soil and unsaturated alluvium at the site. Instead, the contaminants exist as highly contaminated groundwater within the fractures and pore-spaces of the saturated bedrock. The areas of highly contaminated groundwater act as a continuing source for dissolved phased groundwater contamination within the bedrock at the site. Most of these areas of highly contaminated groundwater exist in topographically high portions of the site. The CSM for PJKS is that the contaminated bedrock groundwater flows from the areas of highly contaminated groundwater and discharges into, and results in the contamination of, the saturated alluvial materials along and adjacent to the stream channels. Note that there has been no evidence of separate phases of contaminants found during any of the extensive groundwater contaminant investigations conducted at PJKS.

Alluvial Groundwater

The CSM for PJKS does not include specific feature-related sources for the alluvial groundwater contamination. Instead, the alluvial groundwater contamination appears to be the result of the transfer (discharge) of contaminants from the bedrock groundwater source areas in the topographically high areas of the site to the saturated alluvial materials that line the stream valleys. As a result, the COCs that both exceed state groundwater standard and pose an unacceptable risk to human health, TCE and NDMA, in the alluvial groundwater are the same as those for the bedrock source areas. Once again, the daughter products for TCE have also been included as COCs in the event reductive dechlorination processes produce any byproducts.

The RAO developed for groundwater is inclusive of all groundwater regardless of origin: bedrock or alluvium. However the treatment of the COCs will require different technological approaches based on the constraints that the various formations present.

Exposure Scenarios

The primary threat to the environment due to the COCs in groundwater is the potential for TCE and NDMA contaminated groundwater to impact surface water quality. Twenty plus years of PJKS specific monitoring data has shown that the discharge of contaminated groundwater to surface streams does not result in an exceedence of State of Colorado Basic Standards for Surface Water. Thus, there is no threat to the environment via the transfer of contaminants from ground water to surface water exposure scenario.

The exposure scenario that represents the primary threat to human health due to the contaminated groundwater is via ingestion by the industrial workers at the PJKS and Lockheed Martin sites via drinking water from a well or contact with groundwater in an excavation.

Preliminary Remediation Goals (PRGs)/Media Cleanup Standards (MCSs)

The State of Colorado has promulgated groundwater standards that will be the basis of the PRGs/MCSs for individual contaminants in PJKS groundwater. The State of Colorado Basic Standards for Ground Water (CBSGs) (5 Code of Colorado Regulations 1002-41) apply to all groundwaters of the state, regardless of whether it is currently being used and regardless of whether it can be extracted at a useable quantity or rate. As a result, the long-term RAO for groundwater for any clean-up project in the State of Colorado is achievement of the state groundwater standards throughout the groundwater plume. CERCLA also requires compliance with PRGs/MCSs throughout the plume. The PRGs/MCSs for PJKS groundwater are listed in Table 6.

Both CERCLA and the State of Colorado encourage the use of an initial point of compliance that is initially coincident to the downgradient edge of the plume or the facility property boundary (whichever is closest to the initial source) and an initial period of time to come into compliance. The point of compliance is the PJKS property boundary and the intent of the PJKS groundwater remedial actions is to achieve the PRGs/MCSs at the point of compliance in a reasonable timeframe. The timeframe required to achieve compliance with the state groundwater standards throughout the plume, if even possible, is acknowledged to be a much longer period of time. As described in Sections 4.3 and 4.4, two independent timeframes will be considered for TCE and NDMA based on differing fate and transport mechanics and treatment technologies available.

4.2 RAO CRITERIA

The PJKS RAOs were developed using CERCLA criteria, RCRA MCO criteria, and CDPHE’s Corrective Action Guidance performance standards for groundwater (CDPHE, 2002). The RCRA corrective action process mirrors the CERCLA response process. The primary RAO for contaminated groundwater at PJKS is protection of human health and the environment.

The protection of the environment RAO for PJKS groundwater is to return the bedrock and alluvial groundwater beneficial use to the extent practical using active treatment of TCE in the bedrock source areas.

The primary protection of human health RAO for PJKS groundwater is to prohibit the productive use of all PJKS sourced contaminated groundwater through the use of an institutional control called an Environmental Covenant. An Environmental Covenant places land use restrictions, that are enforceable by CDPHE, into the deed for a property. The original sales agreement for PJKS between the Air Force and Lockheed Martin allowed for the use of an Environmental Covenant to prevent any future use of the groundwater beneath the PJKS site itself. The Memorandum of Agreement between Lockheed Martin and the Air Force states that Lockheed Martin will place an Environmental Covenant (Lockheed Martin Covenant) on the portion of their property that is impacted by PJKS sourced contaminated groundwater (Lockheed Martin, 2010).

The prohibition on any use of the contaminated groundwater will eliminate the human consumption pathway. The prohibition on the use of alluvial groundwater on the Lockheed Martin that is impacted by PJKS sourced contaminated groundwater will only remain in-place until CBSGs are achieved. The prohibition on any use of all groundwater on the PJKS site will remain in place as long as it is needed.

In addition to the overall RAOs described above, the CDPHE Corrective Action Guidance (CDPHE, 2002) includes performance standards that indicate that remedies for the groundwater medium should be capable of performing, at a minimum, one of the following:

• Halt the continued migration of groundwater contamination beyond the PJKS boundary at concentrations in excess of health-based or state-established standards, or

• Halt the continued expansion of the contaminant plume if confined within the boundaries of the PJKS facility.

As described in Section 4.4 and Section 6.0, the USAF is requesting a front-end TI waiver for NDMA in the bedrock source area groundwater at PJKS since the bench scale study results and site-specific pilot study results did not produce a viable remedial alternative to reduce the concentration of NDMA in groundwater. As a result, the final remedy initially selected for PJKS groundwater will not include active remediation of NDMA in bedrock groundwater. Since new remedial technologies for cleaning up groundwater contamination are being developed on a regular basis, the formal Five-Year Review of the PJKS site final remedy will include research into, and possibly testing of, potential new remedial technologies for treating NDMA in groundwater.

4.3 RAOS FOR TCE

4.3.1 RAOs for TCE in Bedrock Source Areas

The seven primary TCE bedrock source areas that have been identified at PJKS are D-1, D-4, EPL, SCA, T-8A, CSSA, and OTL. The groundwater RAOs and PRG(s)/MCS(s) for the bedrock source areas are listed in Table 6. The primary exposure pathway is ingestion by onsite industrial workers and the primary RAO is to prevent industrial workers from ingesting or contacting the bedrock groundwater. This will be accomplished via the PJKS Covenant that will prevent any use of the TCE contaminated bedrock groundwater until TCE concentrations in groundwater are below the ARAR(s) and MCS(s).

The Air Force has implemented ICMs (non-time critical removal actions) in all TCE bedrock source areas at PJKS to help achieve both RAOs and MCOs by reducing the contaminant concentrations over time. The remedies will continue to operate as ICMs or will be administratively converted to final remedies through the preparation of this FFS and completion of a ROD for the groundwater medium.

The data necessary to prepare the long-term groundwater medium RAOs for TCE were available from the numerous investigations, treatability studies, and ICMs that have been completed and are on-going. Based on the criteria of both CERCLA and RCRA, the following RAOs adequately address actual or potential risks posed by the groundwater medium:

Continue the operation of the early action for TCE in bedrock source areas until the concentration of TCE and its daughter products in the bedrock groundwater source areas are considered asymptotic or meet CBSGs. The asymptotic concentration of TCE in bedrock source areas until one of three conditions are achieved:

1. The concentration of TCE and its daughter products meet CBSGs in a particular source area, or
2. It is determined that further treatment will not result in further reductions in TCE in the bedrock groundwater in a particular source area. This is generally agreed to be the time when TCE concentrations in bedrock groundwater over time reach an asymptotic concentraton. The concentration of TCE in bedrock source areas at the time asymptotic conditions are reached will be an alternate PRG/MCS for that particular source area. The asymptotic conditions will be proved and graphed using groundwater monitoring performance data generated during the ICMs and pilot tests. Achievement of this asymptotic criteria will show source area degradation at the point where it is no longer feasible or practicable to continue treatment. Or,
3. The concentrations of TCE and it’s daughter products in the source areas are low enough that they no longer cause an exceedence of CBSGs in the alluvial groundwater at the PJKS Site boundary.

4.3.2 RAOs for TCE in Alluvial Groundwater

The primary exposure pathway for TCE contaminated alluvial groundwater is via ingestion and inhalation by onsite industrial workers. Contaminated alluvial groundwater occurs in all three groundwater SWMUs at PJKS and the primary RAO is to prevent industrial workers from ingesting or contacting the contaminated alluvial groundwater. This will be accomplished via both the Lockheed Martin Covenant and the PJKS Covenant that will prevent any use of the TCE contaminated alluvial groundwater until TCE concentrations in groundwater are below the ARAR(s) and PRGs/MCS(s). The RAO for the inhalation pathway will also be achieved via the Environmental Covenant by ensuring that any inhabited structure over the TCE contaminated alluvial groundwater are equipped with measures to prevent intrusion of vapors into the breathing air.

A second RAO for TCE in alluvial groundwater is to reduce the concentration of TCE in the alluvial groundwater through the operation of the bedrock groundwater source area treatment actions. One possible criteria for stopping the operation of the bedrock source area treatment is achievement of the CBSGs in alluvial groundwater at the point of compliance (i.e., PJKS site boundary).

A cleanup time frame at the point of compliance using the bedrock source area treatment has been estimated for TCE based on the existing ICM treatments. Estimated times to achieve CBSGs at the point of compliance for the seven source areas ranged from 0-49 months.

4.4 RAOS FOR NDMA

4.4.1 RAOs for NDMA in Bedrock Source Areas

The four primary NDMA bedrock source areas that have been identified at PJKS are D-1, SCA, T-8A and CSSA. The groundwater RAOs for the bedrock source areas are listed in Table 6. The primary exposure pathway is ingestion by onsite industrial workers and the primary RAO is to prevent industrial workers from ingesting or contacting the bedrock groundwater. This will be accomplished via the PJKS Covenant that will prevent any use of the NDMA contaminated bedrock groundwater.

Similar to the RAOs for TCE presented in Section 4.3, the data necessary to prepare the groundwater medium RAOs for NDMA were available from the numerous investigations and treatability/bench studies that have been completed. Based on the criteria of both CERCLA and RCRA, the following RAOs adequately address actual or potential risks posed by the groundwater medium:

- Reduce the concentrations of COCs in bedrock groundwater source areas to concentrations that achieve CBSGs for groundwater that is migrating off site or as much as is technically practicable (RAOs for the COCs in groundwater at the point of compliance are presented in Table 6).

In the event the ARAR(s) or MCS(s) cannot be achieved based on limiting site characteristics, as is the case at PJKS, a waiver must be used. CERCLA provides six circumstances for using waivers and RCRA provides three circumstances. A TI waiver is available under both laws where site characteristics prohibit the engineering feasibility or reliability of a remedy to meet the ARARs or MCS. TI waivers are classified as either front-end or post-implementation, depending on the operation of a full-scale remedy.

The USAF is requesting the use of a front-end TI waiver for NDMA in the bedrock source areas at PJKS based on the site characteristics, contaminant characteristics, research and investigation results, bench scale treatability study results, and on-site pilot study results (See Section 6). Neither the research nor the site-specific studies have produced a viable remedial alternative to reduce the concentration of NDMA in groundwater. As a result, the final remedy initially selected for PJKS groundwater will not include active remediation of the NDMA in bedrock source areas. The detailed information supporting the front-end TI Waiver is provided in Section 6.

Numerous pilot studies and bench scale studies (see Section 5.0) have determined the NDMA is either not responsive to practical treatment methods, or cannot be treated with practical methods in a reasonable time frame or within a reasonable budget. Under the provisions defined in CERCLA §121(d)(4)(C) and RCRA Sections 264.525(d)(2) and 264.531 of the Proposed Subpart S rule, in the event that an ARAR(s) or MCS cannot be achieved, based on limiting site characteristics or engineering impracticability, one or more ARARs may be waived (EPA, 1993). In accordance with the RAOs, a TI evaluation for NDMA treatment in the groundwater source areas at PJKS is included in this FFS.

Since new remedial technologies for cleaning up groundwater contamination are being developed on a regular basis, the formal Five-Year Review of the PJKS final remedy will include research into, and possibly testing of, potential new remedial technologies for treating NDMA in groundwater.

4.4.2 RAOs for NDMA in Alluvial Groundwater

The primary exposure pathway for NDMA contaminated alluvial groundwater is also via ingestion by onsite industrial workers. Contaminated alluvial groundwater occurs in all three groundwater SWMUs at PJKS and the RAO is to prevent industrial workers from ingesting or contacting the contaminated alluvial groundwater. This will be accomplished via both the Lockheed Martin Covenant and the PJKS Covenant that will prevent any use of the NDMA contaminated alluvial groundwater until NDMA concentrations in groundwater are below the ARAR(s) and PRGs/MCSs.

5.0 TREATABILITY STUDY AND ICM PERFORMANCE RESULTS

The two reasons for performing treatability studies are: (1) provide data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis; and (2) reduce the cost and performance uncertainties for treatment performance to acceptable levels. Several treatability investigations, pilot studies, and bench scale tests have been conducted at PJKS. Additionally, an on-going ICM for TCE remediation in groundwater at all source areas has proven to be effective in promoting ARD through the introduction of substrates and microbes originally tested as part of the pilot studies. Sufficient data for adequately assessing the feasibility of remedial technologies have been gathered at PJKS through the studies, bench tests, and ICMs.

The following timeline summarizes the date, contaminant and area where the tests, studies, and ICMs were performed:

PJKS Tests/Studies/ICMs	TCE	TCE and NDMA	Dates
Bedrock Pilot Study: D-1, EPL, SCA	X		December 2003 – May 2006
In-Situ NDMA Bench Scale Test: SCA		X	2003
Ex-Situ NDMA Bench Scale Test: SCA		X	2005
Ex-Situ NDMA Pilot Test: SCA/T-8A		X	January 2006 – January 2007
ICMs: D-1, D-4 FSA, EPL, SCA, CSSA, OTL, T-8A, and Biobarriers	X		July 2006 – present

5.1 BEDROCK PILOT STUDY

To evaluate the effectiveness of in-situ ARD on the degradation of TCE and NDMA in bedrock source areas, a bedrock pilot study followed by a supplemental pilot study was conducted at PJKS. The initial bedrock pilot study was completed at three locations at PJKS: the D-1 source area, the EPL source area, and the SCA source area. The groundwater in these areas is contaminated with either TCE only, or both TCE and NDMA. These three source areas are also representative of two of the bedrock aquifers identified at PJKS. The D-1 source area is located in the Precambrian aquifer, and the SCA and EPL source areas are located in the Fountain Formation aquifer. Results from the Bedrock Pilot Study indicated that ARD can be used to successfully treat TCE in the Precambrian aquifer; however, initial results for the Fountain Formation aquifer were inconclusive. Therefore, the EPL area was selected for the supplemental pilot study to further evaluate the effectiveness of ARD to treat TCE in the Fountain Formation aquifer.

The initial results of the bedrock pilot study indicated ARD was not successfully treating NDMA.

5.1.1 D-1 Pilot Test

One monitoring well and one injection well was installed in the D-1 plume as part of the bedrock pilot study. During the study, 249 gallons of sodium lactate (carbon source) was injected into the well beginning in December 2003. Groundwater performance monitoring samples were collected from two wells (including the newly installed downgradient monitoring well) from December 2003 to April 2006. The samples showed a decrease in both DO and ORP within 12 days of the initial injection of sodium lactate. The TCE concentrations decreased from an initial value of 12,000 µg/L to a final value of 640 µg/L in 30 months. In addition, TCE degradation products cis-1,2-DCE, VC, and ethene were detected in the samples. Analyses of the pilot study results indicate that ARD was converting TCE to ethene; however, no significant NDMA reduction appeared to be occurring. The pilot study was converted into an ICM so that treatment could continue. To date, TCE continues to decline and is below 100 µg/L. Detailed results of the pilot tests are summarized in the *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b).

5.1.2 EPL Pilot Test

Two monitoring wells and two injection wells were installed in the EPL area as part of the bedrock pilot study. During the study, 662 gallons of sodium lactate were injected into the wells beginning in December 2003. Groundwater performance monitoring was conducted from December 2003 to April 2006. No evidence of TCE degradation was initially observed. In addition, a strong, downward gradient exists in the EPL area (Shaw, 2007a). Based on the lack of TCE degradation observed, and this known downward gradient, it was determined that additional deeper groundwater monitoring wells were needed to evaluate the distribution of the sodium lactate in the aquifer. Four additional monitoring wells were installed in this area as part of the supplemental pilot study. Bioaugmentation was also tested as part of this effort. A bioaugmentation culture is added to enhance biodegradation in a given media. Bioaugmentation is achieved by adding specific microorganisms to the media. In this case, the microbes that are being injected were initially collected from the successful D-1 Pilot Study location. Those microbes were cultured in the laboratory to increase the mass of microbes. Microbes (Dehalococcoides ethenogenes [DHC]) that have demonstrated the ability to completely degrade TCE to ethene were also introduced into the Fountain Formation in the EPL area in May 2006. Additional groundwater performance monitoring samples were collected from December 2005 to October 2006. Groundwater performance monitoring samples from one well showed a decrease in TCE concentrations accompanied by the appearance of all the TCE degradation products. These results indicated that with the addition of the bioaugmentation culture, in-situ ARD can successfully degrade TCE in the Fountain Formation. Detailed results of the pilot tests are summarized in the *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b).

5.1.3 SCA Pilot Test

Two monitoring wells and four injection wells were installed in the SCA area as part of the bedrock pilot study. During the study, 45 gallons of Hydrogen Release Compound® (HRC®) were injected into the wells beginning in December 2003. HRC® is another type of carbon source used to promote ARD to support TCE degradation. Groundwater performance monitoring samples were collected from three wells (including the newly installed monitoring wells) from December 2003 to April 2006. In all three wells, ORP remained positive in the majority of samples collected, DO did not decrease significantly, sulfate did not decrease, and there was no decrease in TCE concentrations.

This data indicated that HRC® did not produce ARD at the SCA area. However, downward vertical gradients similar to the EPL area are also present at SCA. Therefore, it is likely that the effect of the treatment was occurring below the screened interval of the monitoring wells, although no additional wells were installed to confirm this possibility. Detailed results of the pilot tests are summarized in the *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b).

5.2 IN-SITU NDMA BENCH SCALE TEST

Biodegradation was studied at the bench-scale level and conducted at the Shaw Lawrenceville Laboratory using aquifer material and groundwater collected from PJKS sources. During this study that was funded by the National Science Foundation (NSF), Shaw's Biotechnology Development and Applications Group (formerly Envirogen, Inc.) demonstrated that in-situ bioremediation of NDMA may be feasible using the addition of specific co-substrates (toluene-oxidizers and propanotrophs) to stimulate naturally occurring or exogenous bacteria (Envirogen Inc., 2003). As a result of the NSF study, a bench-scale study was conducted on groundwater from PJKS to evaluate the feasibility of using in-situ biodegradation for NDMA and TCE treatment. Because NDMA and TCE contamination occur concurrently in PJKS groundwater and both are targets of toluene-oxidizers and propanotrophs, the joint treatment of these co-contaminants by both classes of organisms was tested (Hatzinger, 2004). Results of the study indicated that bioremediation of NDMA was not successful; although TCE concentrations were reduced by orders of magnitude through aerobic and anaerobic treatments. However, ARD has been determined to be efficient and cost-effective in reducing TCE concentrations and is the preferred in-situ TCE treatment for PJKS groundwater. Detailed results of the in-situ bench scale test are summarized in the *Groundwater Treatment Studies Report, N-nitrosodimethylamine with Trichloroethene* (Shaw, 2008a).

5.3 EX-SITU NDMA BENCH SCALE TEST

Catalytic hydrogenation was also studied at the bench-scale level and conducted at Shaw Lawrenceville Laboratory using aquifer material and groundwater collected from PJKS sources. Testing was conducted to evaluate the use of nickel catalysts for the treatment of TCE and NDMA in groundwater. A commercially available nickel catalyst and dissolved hydrogen were used to treat the target contaminants. Data collected during preliminary testing showed that nickel catalysts are able to rapidly degrade aqueous mixtures of chlorinated ethenes and NDMA. Similar experiments performed using natural groundwater also showed rapid degradation of tetrachloroethene, TCE, and NDMA. Separate analyses showed that ethane is the final degradation product for the chlorinated ethenes, and ammonia and methane are the final degradation products for NDMA (Shaw, 2005e; Schaefer et al., 2007). As a result of the Shaw Lawrenceville Laboratory's preliminary studies, a bench-scale study was conducted on PJKS groundwater to evaluate the feasibility of using an ex-situ nickel catalyst system for NDMA and TCE treatment (Appendix C). The bench-scale study consisted of two tasks: 1) a preliminary microcosm screening test, and 2) a test using the existing bench-scale reactor. Treatment of NDMA to low levels was observed during a 28-day study, with very little observed catalyst deactivation. The results of the bench scale test showed that NDMA was completely denitrified, generating ammonia as an end-product. Treatment of greater than 95 percent of the TCE was also observed, with no formation of chlorinated daughter products. The test results indicated that treatment of NDMA to 0.001 μg/L using nickel catalysts is attainable. Detailed results of the ex-situ bench scale test are summarized in the *Groundwater Treatment Studies Report, N-nitrosodimethylamine with Trichloroethene* (Shaw, 2008a).

5.4 EX-SITU NDMA PILOT TEST

The ex-situ NDMA bench-scale study (Section 5.3) indicated that evaluation of the nickel catalyst technology in a field demonstration was warranted with the recommendation that the field trial incorporate water softening as a pretreatment step. Design and construction of a scaled-up version of the bench-scale nickel catalyst technology system began in January 2006. The initial construction was completed, and reactor operation was initiated on April 19, 2006 and terminated on January 12, 2007. The reactor was operated in a semibatch mode during the workweek. The reactor was either shut down or operated in recirculation mode (with the hydrogen source turned off) during the weekends for safety reasons. The nickel catalyst field demonstration system attained some of the overall objectives of the project. Specific findings of the field demonstration include the following:

- The nickel catalyst proved effective in treating commingled NDMA and TCE in groundwater under field conditions.
- Treatment of NDMA to concentrations below 0.7 μg/L was attained and maintained for approximately 11 weeks (October 2006 through January 2007). Approximately 2,100 gallons of water were treated during this period.
- NDMA degradation kinetics observed in the field demonstration system are consistent with those observed in the laboratory bench-scale system.

Dissolved nickel in the effluent, as observed during the demonstration, is problematic. The concentration of dissolved nickel substantially exceeded the CBSG value of 100 μg/L. The system performance resulted in a conclusion that full scale deployment of the technology at PJKS is not feasible. Furthermore, the alluvial aquifer well chosen for this effort was approximately 25 ft bgs and allowed for easy groundwater recovery with very high hydraulic conductivity rates (11.4177 ft/day) (Table 10.3.5.4.3-1, Parsons, 1999).

Detailed results of the pilot test are summarized in the *Groundwater Treatment Studies Report, N-nitrosodimethylamine with Trichloroethene* (Shaw, 2008a).

5.5 INTERIM CORRECTIVE MEAURES

Result of previous pilot studies that were being conducted at PJKS indicate that sodium lactate is an effective substrate for enhancing the biodegradation of TCE at PJKS. *Currently ICMs have been initiated at all seven groundwater source areas. ARD is* being stimulated in the Fountain Formation and Precambrian aquifers at these source areas by injecting sodium lactate and a bioaugmentation culture in specific wells in these areas. The purpose of ARD in the source areas is to reduce contaminant concentrations in the source areas to levels that will ultimately achieve RAOs at the point of compliance. In addition to treating the source areas, ARD is being enhanced at the transition points (the point at which the groundwater moves from the bedrock to the alluvium as illustrated on Figure 12) of the Fountain and Alluvial aquifers by constructing two biobarriers, originating from the SCA and the OTL/T-8A source areas, and injecting a mixture of edible emulsified oil (EEO), water, and DHC. At the SCA transition point, EEO and DHC were injected along a 300 foot linear alignment perpendicular to the East Fork of Brush Creek near the PJKS boundary. At the OTL/T-8A transition point, EEO and DHC were injected along a 150 foot linear alignment perpendicular to the West Fork of Brush Creek near the PJKS boundary (see Figure 10).

In the Fountain and Precambrian aquifers, the injection of sodium lactate was pulsed initially, until adjacent monitoring wells indicate that reducing conditions are occurring. The sodium lactate solution was approximately 1 to 5 percent by volume solution and introduced to the aquifer using gravity feed totes. The volume and concentration of the sodium lactate mixture includes water, sodium lactate (WilClear brand, 66 percent concentration). The bioaugmentation culture was added to enhance biodegradation in a given media. Those microbes (DHC) were cultured in the laboratory to increase the mass of microbes. The microbes are pumped below the water table (approximately 5 to 10 gallons) for each applicable injection well. EEO is now being used in the source areas solely without the DHC bioaugmentation culture.

For chlorinated solvents, a successful source area treatment results in the stepwise biodegradation of TCE to the degradation by-products *cis*-1,2-DCE and VC. The final degradation by-product of TCE is the non-chlorinated hydrocarbon ethene and chloride. This biodegradation process has been successfully demonstrated in-situ at the PJKS source areas.

5.5.1 **D-1 Source Area**

Sodium lactate injection at the D-1 source area began in October 2006. Baseline samples were collected just prior to that in July and August 2006. A second injection of sodium lactate was completed in August 2007, and the most current injection occurred in March 2008. In accordance with the *Implementation Work Plan, D-1 Area Groundwater Plume, Interim Corrective Measure* (Shaw, 2006b), sodium lactate is injected biannually. ICM activities are also being completed at the D-1 Tributary in accordance with the *Groundwater Source Areas ICM Work Plan* (Shaw, 2007a). The D-1 tributary is a subset of the D-1 source area and is not considered a separate source area (see Figure 10). The first injection of sodium lactate at the D-1 Tributary occurred in March 2008, bioaugmentation culture was also added to these wells in March 2008. A total of five vertical injection/monitoring wells are included in the ICM activities. Seven additional vertical wells are also monitored to evaluate the effectiveness of the bioremediation.

Analytical results for the D-1 plume for the fourth quarter (Sept 2009) indicate increasing TCE concentrations in wells IV-1-MW4, BCMW-018-P, BCMW-020-P, and 5-M07, although concentrations are still well below baseline concentrations. Only well IV-1-MW4B reported decreased TCE concentrations. These increasing concentrations of TCE are likely due to the fact that sodium lactate has not been injected since March 2008, approximately 18 month duration. These data suggest that the effectiveness of sodium lactate is between 6 and 12 months. Future injections should consist of EEO to increase the interval between injections. As indicated by positive ORP values and above-target DO values, ARD conditions have not yet been achieved in the D-1 Tributary.

5.5.2 **D-4 FSA Source Area**

Sodium lactate injection at the D-4 FSA source area began in November 2006; baseline samples were collected just prior to that in July 2006. A second injection of sodium lactate (in addition to bioaugmentation culture) was completed in July 2007, and the most current injection occurred in March 2008. In accordance with the *Implementation Work Plan, D-4 Fuel Storage Area, Interim*

Corrective Measure (Shaw, 2006c), sodium lactate is to be injected biannually. A total of five vertical injection/monitoring wells are included in the ICM activities. Seven additional vertical wells are also monitored to evaluate the effectiveness of the bioremediation.

Analytical results from the fourth quarter (Sept 2009) indicate that DO and ORP continue to decrease to below target values in the D-4 FSA wells where sodium lactate mixture was introduced. Wells LGMW-018-P, LGMW-019-P, LGMW-030-P, and 3-M14B are showing overall degradation based on the decrease in TCE values. However, the most recent results show an increase in TCE concentrations for all wells sampled with the exception of 3-M14B and LGMW-030-P, again due to the 18 month duration since the last sodium lactate injection. It is recommended that additional injections be performed in the D-4 FSA, with future injections consisting of EEO to increase the interval between injections.

5.5.3 EPL Source Area

Sodium lactate and bioaugmentation culture injection at the EPL source area began in August/September 2007; baseline samples were collected just prior to that in May 2007. A second injection of sodium lactate was completed in November/December 2007, and the most current injection occurred May to September 2009. In accordance with the *Groundwater Source Areas ICM Work Plan* (Shaw, 2007a), the frequency of sodium lactate injections will be evaluated on an ongoing basis. One cluster of directional injection/monitoring wells is included in the ICM activities. Two additional vertical wells are also monitored to evaluate the effectiveness of the bioremediation.

Analytical results for the EPL area for the fourth quarter (Sept 2009) indicate DO and ORP have begun to increase to above target levels. However, the combination of decreasing TCE and increasing cis-1,2-DCE suggest ARD is occurring. Recommendations are to continue injecting in the EPL Area, with future injections consisting of EEO to increase the interval between injections.

5.5.4 SCA Source Area

Sodium lactate and bioaugmentation culture injection at the SCA source area began in November/December 2007; baseline samples were collected just prior to that in June 2007. A second injection of sodium lactate and bioaugmentation culture was completed in January 2008, and the most current injection occurred May to September 2009. Two clusters of directional injection/monitoring wells are included in the ICM activities. Two additional vertical wells are also monitored to evaluate the effectiveness of the bioremediation.

Fourth quarter analytical results (Sept 2009) for the SCA area indicate that ARD is successfully reducing the TCE concentrations in the source area. When compared, the last two rounds of sampling show a decrease in TCE concentration for all wells sampled. DO and ORP levels have decreased below target levels indicating no immediate need for additional carbon source to support ARD.

5.5.5 CSSA, OTL, and T-8A Source Areas

Sodium lactate and bioaugmentation culture injection at the CSSA, OTL, and T-8A source areas began in March/April 2008; baseline samples were collected just prior to that in February 2008.

A total of five vertical injection/monitoring wells are included in the ICM activities at CSSA. Fourth quarter analytical results (Sept 2009) shows a trend for decreasing DO and ORP values that are in range of the ARD process, as well as decreasing TCE concentration. Based on results of the closest monitoring wells, it is likely that the effects of the treatment have not yet reached the more downgradient performance monitoring wells. Recommendations are to continue injecting, with future injections consisting of EEO in order to increase the interval between injections.

Three vertical injection/monitoring wells are included in the ICM activities at OTL. Baseline samples collected from OTL wells originally showed that anaerobic conditions are in place already and have facilitated the TCE degradation to cis-1,2-DCE. Fourth quarter analytical results (Sept 2009) indicate a decrease in TCE and DCE along with a slight increase in VC, which is consistent with ARD. The treatment does not appear to have reached the more downgradient wells. Recommendations are to continue injecting, with future injections consisting of EEO in order to increase the interval between injections.

Two vertical injection/monitoring wells are in included in the ICM activities at T-8A. Baseline samples were collected from the new wells before the sodium lactate and bioaugmentation culture was added, no inferences have been made from these initial samples. Fourth quarter analytical results (Sept 2009) for the T-8A indicate ARD conditions have not yet been achieved based on the DO and ORP values. Therefore it is recommended that additional substrate and sodium lactate be injected in the source area to achieve optimal ARD conditions. Future injections will consist of EEO to increase the interval between injections.

5.5.6 **Biobarriers**

Between April 23, 2008 and June 20, 2008, two biobarriers were constructed perpendicular to the East Fork of Brush Creek (from the SCA source area) and the West Fork of Brush Creek (originating from the T-8A and OTL source areas) near the PJKS boundaries. The East Fork Brush Creek biobarrier is 300 ft long, and the West Fork Brush Creek biobarrier is 150 ft long. The biobarriers consist of an injectant of EEO, a carbon substrate that will dissolve more slowly than sodium lactate and water, and provide a carbon source for DHC for a much longer period. Prior to beginning injections, water levels in monitoring wells in the vicinity of the biobarriers were measured. This information was used to estimate the highest depth of injection. Injections began on the southern portion of the West Fork Brush Creek biobarrier. Injection points were drilled 15 ft apart.

The T-8A/OTL Biobarrier (in the East Fork of Brush Creek) shows a significant change in TCE and daughter products. However, *in-situ* DO and ORP measurements indicate DO and ORP ranges similar to the locations downgradient from the SCA alluvial biobarrier. The SCA Alluvial Biobarrier (in the West Fork of Brush Creek) downgradient wells show decreasing TCE and DCE along with increasing VC, indicating ARD is occurring.

6.0 TECHNICAL IMPRACTICABILITY EVALUATION

In the event that applicable or relevant and appropriate requirement (ARAR(s)) or media cleanup standards (MCS) cannot be achieved, based on limiting site characteristics or engineering impracticability, one or more ARARs may be waived by EPA (or the lead agency, CDPHE) under the provisions defined in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121(d)(4)(C) and Resource Conservation and Recovery Act (RCRA) Sections 264.525(d)(2) and 264.531 of the Proposed Subpart S rule. CERCLA provides six circumstances for using waivers and RCRA provides three circumstances. While the processes the two programs use to establish cleanup levels differ (e.g., the ARAR concept is not used in RCRA), the primary considerations for determining the technical impracticability (TI) of achieving those levels are identical (EPA, 1993):

- Engineering feasibility, and
- Reliability.

TI waivers are classified as either front-end or post-implementation, depending on the operation of a full-scale remedy. The TI waiver process varies slightly for each.

A front-end TI waiver for NDMA in the groundwater bedrock source areas at PJKS is being sought. A "front-end" TI decision (i.e., a decision that is made before a final remedy decision document has been signed), is justified based on previous CERCLA and RCRA remedial investigations, and the information provided in the Focused Feasibility Study (FFS) (Shaw, 2010c). A TI waiver is based on site characteristics, contaminant characteristics, investigation results, and pilot study results. Data from previous studies show the restoration potential of the source areas is such that achieving the ARARs and MCS for NDMA may be technically impracticable from an engineering feasibility perspective. Information will be provided to show that contaminant source constraints combined with geological constraints severely limit the ability to treat NDMA within the bedrock aquifers. The quantity, distribution, and properties of the contamination, as well as the presence of complex fracturing of bedrock aquifers at PJKS, render NDMA removal from, or destruction within, the subsurface environment infeasible or inordinately expensive. The TI application will be supported using data from ongoing remediation, pilot tests, site models, and/or a literature review.

In instances where it is technically impracticable to fully remediate a site, resources can be focused towards minimizing exposure and risks to human and environmental receptors instead of cleanup. Funding that would otherwise be spent on ineffective cleanup can be focused on site management and the use of institutional and/or engineering controls. The advantage of a TI waiver is that it provides financial relief where continued cleanup of contaminated sites provides little to no benefit versus the cost of cleanup.

The application process for TI waiver includes three main components:

- Adequate site characterization and development of a conceptual site model (CSM)
- Notification and consultation with the EPA and CDPHE
- Completion of a TI Evaluation report

The results of several remedial/site investigations have resulted in full characterization of NDMA contamination in groundwater at PJKS. The USAF, CDPHE, and EPA had preliminary discussions regarding a potential need for a TI waiver; however, a formal application has not been submitted, nor has a formal consultation been requested. Prior to submitting the application, the TI evaluation must be completed. Five TI evaluation components are required for a TI waiver (EPA, 1993): ARAR/MCS for which TI is sought, TI zone, CSM, restoration potential, and cost.

6.1 ARARS

A TI waiver is sought for chemical-specific ARARs applicable to NDMA concentrations in groundwater. Chemical-specific ARARs that have been identified for groundwater are discussed in the FFS and Table 1.

NDMA is not listed as a drinking water contaminant in the Colorado Primary Drinking Water Regulations (5 Code of Colorado Regulations [CCR] 1003-1); therefore, a waiver is not required for this ARAR. Furthermore, NDMA does not have a Maximum Contaminant Level per the National Primary Drinking Water Regulations. The Colorado Rules and Regulations Pertaining to Hazardous Waste set criteria for listing of hazardous waste; however, does not establish cleanup criteria; no waiver is required for this ARAR. Alternate Concentration Limits (40 Code of Federal Regulations [CFR] 264, Subpart F) for NDMA in groundwater are not being requested; therefore, RCRA does not require a waiver. Under the Clean Water Act, the Water Quality Standards (40 CFR 131) for NDMA are 0.00069 µg/L for human health consumption (water + organism) and 8.1 µg/L for organism only. The CBSG (5 CCR 1002-41) also sets the standard cleanup level for NDMA at 0.00069 µg/L. However, Colorado regulations state that if a standard is below the PQL of the approved analytical method, the PQL is the enforcement standard. The PQL for the currently approved method is 0.05 µg/L, which has been established as the remedial action objective (RAO) for NDMA at this site. Numerous investigations, bench-scale studies, pilot studies, and research have indicated that a 0.05 µg/L cleanup goal for NDMA is not attainable in the bedrock source area at PJKS. Therefore, a determination of impracticability is sought for the chemical-specific ARAR, CBSG (5 CCR 1002-41)

Per EPA guidance (EPA, 1993), factors that are used to evaluate TI waivers include:

- The technical feasibility of restoring some of the contaminants present in the groundwater, and

- The potential advantage of attaining cleanup levels for some of the contaminants.

6.2 TI ZONE

The horizontal extent of the area for which the TI determination is being sought is defined by the extent of the bedrock (Fountain Formation and Precambrian) NDMA contaminant plume. NDMA plume maps were prepared for the 2004 Annual Groundwater Monitoring Report (Shaw, 2005a) and are included as Figures 15 and 16. Additionally, a 2005 study of NDMA in groundwater yielded similar site maps (Shaw, 2006) More current NDMA plumes maps that cover the same wells have not been recreated because there are fewer NDMA points as the number of wells sampled has been optimized over the years to target the sentinel wells that represent the heart of the NDMA plumes and leading edges. Data collected subsequent to these two sampling events are consistent with historical NDMA concentrations reported and plumes have relatively remained the same from the 2004 through 2009 data sets. The stability of the plume years provides adequate boundaries for the TI zone. The horizontal extent of the TI zone will be defined as the physical coordinates set by the outmost boundaries of the bedrock NDMA plume across the two aquifers as shown in Figure 17.

The vertical extent of the TI zone is defined as the lower-most bedrock aquifer in which NDMA contamination exceeding cleanup standards has been detected. Generally along the east side of PJKS, the Fountain Formation Aquifer is the lower-most aquifer and is composed of sandstone, interbedded with siltstone and claystone. The Precambrian Bedrock Aquifer underlies both the Alluvial and Fountain Formation Aquifers along the west side of PJKS. It is composed of fractured crystalline rock and is the lower-most aquifer. Several Fountain aquifer groundwater wells up to 245 feet (ft) below ground surface were sampled as part of a 2005 NDMA Groundwater Study (Shaw, 2006), as well as sampling from several Precambrian aquifer groundwater wells up to 100 ft below ground surface. These wells define the vertical extent of the TI Zone.

The TI Zone is specific to the bedrock contamination as indicated by the interpretive iso-contours on Figure 17. However, the TI Zone is inclusive of all bedrock aquifer groundwater contamination. There has been a steady state of the NDMA contours in bedrock over the history of the initial investigations and annual sampling programs. Concentrations that remain consistent through time have been used to define a stable plume (Tables 8 and 11, Shaw, 2010b). The maximum aerial extent as observed throughout the sampling history is consistent with the fall 2009 data set.

6.3 CONCEPTUAL SITE MODEL

A CSM has been developed for PJKS and is illustrated graphically as Figures 12 and 13. The interaction of bedrock groundwater into alluvial groundwater occurs at transition points usually at the base of topographic high spots.

The CSM focuses on contaminant sources and releases; and contaminant distribution, transport, and fate parameters. A CSM is submitted every year as part of the Annual Groundwater Report and historically is based on and supported by interpretive graphics, reduced and analyzed data, subsurface investigation logs, and other pertinent information.

6.3.1 Geology

PJKS is located on the eastern flank of the Front Range. It is situated within an alluvium filled, northwest-trending valley (Central Valley) that is bordered on the west by foothills of the Rocky Mountains, and on the east by parallel hogback ridges consisting of sedimentary rocks. The facility is divided into two geographic areas; the Foothills, which comprise the western two-thirds of the facility and the Central Valley, which covers the eastern one-third of the facility. The foothills are defined by rugged, irregular mountains of igneous and metamorphic rocks and unnamed tributaries of the East and West Fork of Brush Creek. In the Central Valley, the primary geographic features include the main streams of the East and West Forks of Brush Creek, Lariat Creek, and the EPL ridge. Elevations range from 7,000 ft above mean sea level (amsl) in the foothills in the western portions of the plant to 5,925 ft amsl in the East Fork Brush Creek drainage near the eastern Plant boundary (Parsons, 1999).

The three geologic units that are associated with groundwater are the alluvium, Fountain Formation, and Precambrian Bedrock. The alluvium is defined as Quaternary age, which is composed of discontinuous layers of unconsolidated clay, sand, silt, gravel, and cobbles. The Pennsylvanian-Permian Fountain Formation makes up the hogback ridges seen at the surface and is composed of sandstone interbedded with siltstone and claystone. The Precambrian fractured crystalline rock underlies both the Quaternary age alluvium and Fountain Formation. The distinct geologic units and the groundwater associated with them result in three very different hydrogeological conditions.

6.3.2 **Hydrogeology**

The geologic diversity at PJKS has resulted in three hydrogeological units; the alluvial aquifer, the Fountain aquifer, and the Precambrian aquifer.

6.3.2.1 Alluvial Aquifer

The alluvial aquifer is unconfined, and the depth to the water table varies seasonally. The alluvium is composed of discontinuous layers of unconsolidated clay, sand, silt, gravel, and cobbles and ranges in saturated thickness from 0 to more than 47 ft. Flow directions in the alluvial aquifer are influenced by surface topography, with groundwater moving from topographic highs to lows. The measured permeability values for the alluvial aquifer range from 1 to 10 ft per day (ft/day), while the average velocity of the groundwater is 1 foot per day. The alluvial aquifer has a transmissivity that ranges from 1 to 3,406 gallons per day per foot, reflecting variations in saturated thickness and hydraulic conductivity.

6.3.2.2 Fountain Aquifer

The saturated portion of the Fountain Formation is considered part of the lower aquifer system and there is no separation from the alluvial aquifer and the underlying Fountain aquifer. Although the two aquifers are hydrologically joined, their hydraulic properties are what separate them. Groundwater flow in the Fountain aquifer is influenced by the structural orientation of bedrock layers, the topography of the land surface, and the varied nature of the Fountain Formation. The Fountain Formation causes the main flow to occur along more permeable layers that are parallel, rather than perpendicular. General flow at PJKS run towards the east and southeast in parallel surface drainages, but in the northern portion of PJKS, the groundwater flows in the north direction towards Lariat Gulch. Since the hydraulic conductivity varies depending on the lithology of the Fountain aquifer, conductivities can range anywhere from 0.00059 ft/day to 3.53 ft/day, with an average of 0.198 ft/day (Tables 9.3.1.4.3-1, 10.2.5.4.3-1, and 10.3.5.4.3-1, Parsons, 1999).

6.3.2.3 Precambrian Aquifer

Beneath the western two-thirds of the PJKS facility lays the Precambrian aquifer. The Precambrian Formation (fractured crystalline rock) underlies both the alluvium and Fountain Formation. The Precambrian aquifer is unconfined and the flow of groundwater is controlled by secondary permeability through joints and fractures. Characterization and fate and transport evaluations are challenging in a fracture flow aquifer. The depth to groundwater ranges anywhere from 7 to 95 ft below ground surface and the permeability rates are from 0.0136 ft/day to 4.83 ft/day with an average of 0.687 ft/day (Parsons, 1999) Conductivities can range anywhere from 0.04165 ft/day to 4.826 ft/day (Tables 10.2.5.4.3-1 and 10.3.5.4.3-1, Parsons, 1999), depending on the geographic location.

6.3.3 Surface Water

The surface water hydrology at PJKS is the primary aboveground migration pathway for contaminants. The major natural watercourse through AFP PJKS is East Fork Brush Creek; its headwaters occurring in the Precambrian foothills west of PJKS. West Fork Brush Creek originates just north of the OTL, and a western branch, called the D-1 Tributary, originates just south of the D-1 Test Stand. Just above the confluence of the South Platte River, the East and West Forks of Brush Creek merge southeast of the Lockheed Martin property. Approximately 1 mile of East Fork Brush Creek and 1,000 ft of West Fork Brush Creek are located within the boundaries of AFP PJKS. Both forks, as well as Lariat Creek are intermittent streams, flowing seasonally in response to snowmelt and precipitation events.

The interaction of surface water and groundwater occurs primarily within the alluvial aquifer. Groundwater discharge from the alluvial aquifer is mostly by subsurface flow at bedrock highs along the eastern and southeastern property boundaries and at two locations along East Fork Brush Creek. Alluvial aquifer groundwater also appears to discharge at two springs in Lariat Gulch, and at seeps along the upper reaches of Brush Creek (Parsons, 1999).

6.3.4 Transport/Fate Media

Potential transport pathways at PJKS and the media within which they occur, are bedrock groundwater, alluvial groundwater, and surface water (see Figure 12).

6.3.5 Contaminant Sources and Releases

Groundwater contamination at PJKS has resulted from activities associated with the development of rocket launch equipment, engine testing, and/or fuels development, purification, and testing. The evaluation of several years of groundwater monitoring data has identified two primary COCs; TCE (the primary COC) and NDMA (less dispersed than TCE). Sources of PJKS contamination were developed from distribution maps of TCE, which were plotted in each of the three groundwater aquifers (the alluvial, Fountain, and Precambrian). Seven source areas were identified. Four of these locations (SCA, D-1, T-8A, and CSSA) were also identified as NDMA source areas. No soil sources for groundwater contamination have been identified. Operational facilities at PJKS were frequently located on bedrock ridges or topographically elevated areas. Contaminated process water infiltrated into the ground surface and subsequently into near surface bedrock. Movement through the bedrock continued downward, and then migrated laterally into shallow alluvial drainage channels. Potential transport pathways and the media within which they occur are bedrock groundwater, alluvial groundwater, and surface water. The CSM, which is graphically illustrated in Figures 12 and 13, is a summary of site conditions that identifies: the type and location of sources of contamination; and how and where people, plants, or animals may be exposed to the contamination.

The NDMA plume appears stable over the past 10 years. Minimal changes to the conceptual site model presented in the Annual Groundwater Reports and the NDMA plume characterization are found when the results of the 2005 NDMA Study (Shaw, 2006) are compared to the results of previous groundwater sampling events. No new source areas or migration pathways were found during the NDMA Study. The results of this study suggest no reason to change the previously-established CSM contained in the OU5 Addendum (Stone & Webster, Inc., 2003).

6.3.6 Current and Potential Receptors

PJKS and the surrounding Lockheed Martin property are currently industrial properties (based on the Order of Consent) with no residential inhabitants. Therefore, under current conditions, human receptors for the groundwater medium associated with contaminants from PJKS would be commercial/industrial workers. Potential routes of exposure include ingestion of groundwater, inhalation of vapors from groundwater, and dermal contact with groundwater, as defined in Section 2.4.5. Contaminants of potential concern in groundwater at the site are inaccessible to terrestrial receptors and there are no completed pathways for aquatic receptors.

6.4 RESTORATION POTENTIAL FOR NDMA IN BEDROCK

The TI of restoring NDMA in groundwater to ARAR/MCS cleanup standards is demonstrated by pilot study and bench-scale study performance data, as well as by a Groundwater Treatment Studies report prepared in 2008 (Shaw, 2008a); included as Appendix C. The supporting information addresses source control, performance/suitability of current actions, remediation time frame estimates, and TI demonstrations.

6.4.1 Source Control

According to EPA guidance (EPA, 1993), *"EPA expects that all reasonable efforts will be made to identify the location of source areas through historical information searches and site characterizations efforts."* As discussed in section 6.3, and in the CSM, four locations (SCA, D-1, T-8A, and CSSA) were identified as NDMA source areas. No soil source areas of NDMA have been identified at the site. However, NDMA concentrations in the bedrock source areas have not significantly changed for the duration of the investigation activities at PJKS. Therefore, if left untreated, these bedrock NDMA source areas will continue to act as the source for the downgradient alluvial plumes and negatively impact the ability to achieve the alluvial RAOs for NDMA. Treatment of the groundwater in these source areas for NDMA is technically impracticable and cost prohibitive (see follow-on discussion).

Options for treating the bedrock NDMA source areas fit into one of two overall categories; ex-situ (e.g. pump and treat) or in-situ (e.g. biodegradation). Several treatability investigations, pilot studies, and bench scale tests have been conducted at PJKS. These studies are discussed in detail in Section 5.0 and summarized here. Sufficient data have been gathered at PJKS through the investigations, studies, and tests for adequately assessing the feasibility of treating NDMA in bedrock groundwater.

A bedrock pilot study followed by a supplemental pilot study was conducted at PJKS. Results are presented in the *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b). These studies included rock coring, packer testing, and tracer testing to evaluate the transmissivity and hydraulic conductivity of the bedrock aquifers. The low hydraulic conductivities measured with the packer testing combined with the uncertain aquifer communication measured with the tracer testing confirms that extraction wells in the bedrock aquifer would have limited effectiveness and therefore a pump and treat system in the bedrock aquifer was not evaluated further.

Two of the areas studied are considered NDMA source areas, D-1 and SCA. At the D-1 plume, 249 gallons of sodium lactate was injected into one well and groundwater performance monitoring samples were collected from two wells to evaluate the effectiveness of sodium lactate treating NDMA in groundwater. The monitoring results showed no significant NDMA reduction. At the SCA area, 45 gallons of HRC® was injected into four injection wells, and groundwater performance monitoring samples were collected from three wells. No decrease in contaminant concentrations was observed.

Initial results of the bedrock pilot study indicated ARD was not successfully treating NDMA; however, additional evaluation of in-situ technologies was conducted. Biodegradation was studied at the bench-scale level. The bench-scale studies were conducted at the Shaw Lawrenceville Laboratory using aquifer material and groundwater collected from PJKS sources (Shaw, 2008a). Results of the in-situ biodegradation study confirmed that bioremediation of NDMA was not successful. Detailed results of the in-situ bench scale test are summarized in the *Groundwater Treatment Studies Report, N-nitrosodimethylamine with Trichloroethene* (Shaw, 2008a).

Where complete source removal or treatment is impracticable, the EPA requires that use of migration or containment measures be considered. The annual groundwater monitoring and the quarterly ICM monitoring programs ongoing at PJKS show that the alluvial NDMA plumes from the operations at PJKS are stabilized; however, the NDMA plumes do extend beyond the PJKS property boundary. Therefore, the USAF evaluated the potential of a boundary containment groundwater extraction system within the PJKS facility and treatment before reaching the PJKS property boundary. This system is the basis for the remediation timeframe estimate and the cost evaluation below.

In the case of PJKS, the NDMA plumes extend only a short distance beyond the PJKS site boundary. The USAF has recently reached an agreement with the downgradient property owner Lockheed Martin that will constitute the final remedy for NDMA in alluvial groundwater. Lockheed Martin will place an environmental covenant on the property where the alluvial groundwater is contaminated with NDMA to prevent future use of the contaminated alluvial groundwater for any purpose. Therefore, there is no need for a boundary control system for NDMA in alluvial groundwater at the PJKS site boundary at this time.

6.4.2 **Performance/Suitability of Current Actions**

The USAF is currently conducting an Annual Sitewide Groundwater Monitoring Program. This program has been in place since 1999 and annual reports are submitted. The program is designed to collect sufficient data to monitor the bedrock source areas and the extent of the downgradient alluvial plumes. Sufficient data have been collected over the duration of the program to document the extent of the bedrock source areas, the extent of the alluvial plumes, and to demonstrate plume stability. The *2009 Annual Groundwater Report* (Shaw, 2010c) summarizes the sampling events conducted during the 2009 field sampling season.

6.4.3 **Remediation Time Frame Estimate**

As discussed above, no alternative to address the bedrock NDMA source areas was identified. Therefore, the remedial timeframe estimate is based on the containment alternative. Extracting groundwater contaminated with NDMA and commingled TCE at the PJKS property boundary and treating it on site is the considered alternative. This alternative would not address the sources of NDMA. The treatment of the contaminated groundwater in the alluvial system at the PJKS boundary would contain the entry of all upgradient groundwater sources. Groundwater would be extracted via gravel-filled trenches and groundwater extraction wells. One technology that has been evaluated for treatment of NDMA- and TCE-contaminated groundwater is a new technology that uses a nickel catalyst and hydrogen. The treatment system would consist of a storage tank and a nickel-catalyst and hydrogen treatment unit. The unit would be equipped with explosion-proof pumps and control panels. The treatment equipment and tank would be housed in an insulated, heated, prefabricated building. The nickel catalyst and hydrogen process is currently considered innovative and, as a result, a treatability process was completed. As discussed in the previous section, a test-scale nickel catalyst technology system was installed and operated at PJKS for nine months. While the nickel catalyst proved effective in treating commingled NDMA and TCE in groundwater under field conditions, regular maintenance was required to keep the filters clear of catalyst material. The results indicated that a larger scale system would require a great deal of maintenance to prevent corrosion of the nickel catalyst. In addition, the presence of dissolved nickel in the effluent, as observed during the demonstration, would be problematic.

Not taking into consideration delays due to maintenance or equipment problems, or any additional treatment required for dissolved nickel in the effluent, the time until protection is achieved using this technology is estimated to be 381 years (Shaw, 2005f). This estimate is based on the time from the most upgradient NDMA source at PJKS (SCA) to the collection trench located at the PJKS property boundary using the average linear groundwater velocities for the various formations. This estimate is likely an underestimate because it assumes the input from the bedrock source area is removed and this is not the case. Based on existing data, it is not possible to estimate the timeframe for the bedrock source area to attenuate.

6.4.4 **Technical Impracticability Demonstration**

The TI evaluation process requires that an evaluation be completed to demonstrate that no other remedial technologies or strategies would be capable of achieving groundwater restoration. Per the EPA guidance (EPA, 1993), the EPA expects that such a demonstration will consist of:

- A review of the technical literature to identify candidate technologies,
- A screening of the candidate technologies based on general site conditions to identify potentially applicable technologies, and
- An analysis, using site hydrogeological and chemical data, of the capability of any of the applicable technologies to achieve the required cleanup standards.

This evaluation was completed and the information summarized in *a Groundwater Treatment Studies Report, N-Nitrosodimethylamine with Trichloroethene, Former USAF Plant PJKS, Waterton Canyon, Colorado* (Shaw, 2008a). A copy of this report is provided as Appendix C and summarized below.

Twenty-two years of comprehensive field investigations conducted by the USAF have determined that TCE and NDMA are the groundwater COCs at PJKS. While NDMA and TCE contamination usually occur simultaneously at PJKS, the Groundwater Treatment Studies report focused on NDMA contamination because an in-situ technology, ARD (which has been proven to be effective at remediating TCE groundwater contamination) does not treat NDMA.

The report included literature research of theoretical, bench-scale, and field-scale NDMA groundwater treatment technologies. The results of the research show that conventional groundwater treatment methods for organic contaminants, including air stripping, absorption on activated carbon, and bacterial degradation, have not been effective in removing NDMA. The compound can form and disassociate by different processes. Groundwater treatment processes may successfully disassociate the compound only to have it re-form later. Other contaminants or dissolved constituents in groundwater can affect treatment success. Several different processes and mechanisms have been used, tested, or proposed to treat NDMA-contaminated groundwater, including:

- Ultra Violet and Ultra Violet Plus Oxidation
- Incineration
- Hydrous Pyrolysis Oxidation
- Biodegradation
- Catalytic Hydrogenation
- Permeable Reactive Barrier (PRB)
- Zeolites

Ultra Violet and Ultra Violet Plus Oxidation: Direct photolysis with ultra violet (UV) at 230 nanometers (nm) (with a range from 200 to 260 nm) breaks the nitrogen-to-nitrogen bonds in NDMA and is itself sufficient to destroy the contaminant. Ultraviolet (UV) plus oxidation has been considered the best available technology for treating NDMA-contaminated groundwater for more than 10 years. Groundwater treated with UV oxidation must be pumped, treated ex-situ onsite, and then discharged; therefore, treatment systems are not appropriate for treating the bedrock source area.

Incineration: Incineration or thermal oxidation destroys NDMA contaminants in water. Incineration is not a practical alternative for groundwater remediation when other options are available. As groundwater must be withdrawn from the aquifer for processing, it becomes unavailable for reuse and is lost as vapor to the atmosphere unless additional recovery equipment is used. Incineration is an expensive pump-and-treat groundwater technology with relatively high capital investment and fuel costs.

Hydrous Pyrolysis Oxidation: A study conducted by the Lawrence Livermore National Laboratory concluded that hydrous pyrolysis oxidation was not a feasible remediation method for NDMA at the test facility (White Sands Missile Test Range) (Leif, et al 1999). The study found that even at ideal conditions, the NDMA destruction half-life would be extremely slow, approaching 2,000 days.

Biodegradation: Biodegradation of NDMA by microorganisms is a technology currently in the research and development stages. Contaminant concentration thresholds pose a difficult problem for biodegradation of NDMA in groundwater. Biodegradation has not, to date, been pilot-tested at a field site where groundwater is contaminated with NDMA. However, a bench-scale bioremediation study was conducted with PJKS alluvial aquifer material and groundwater is presented in Section 4.1.1 of this report.

Catalytic Hydrogenation: Independent laboratory studies conducted prior to 2000 indicated that NDMA in groundwater could be ultimately decomposed to dimethylamine and ammonia by catalytic hydrogenation with nickel as the catalyst when plated on granular iron or alloyed with aluminum (Greene, et al, 2000). Although catalytic hydrogenation for the destruction of NDMA was reported as a promising remedial technique, the possibility that NDMA could re-form in treated solutions has not been addressed. A nickel catalyst NDMA treatability study, which included bench-scale and field demonstration components, was conducted using PJKS groundwater. The bench-scale and field demonstration results are presented in Section 4.1.1.

Permeable Reactive Barrier: A PRB consists of a wall of reactive material that has been installed in the path of a flowing, contaminated, groundwater plume. Contaminants are treated as the groundwater penetrates the wall, which is designed to be more permeable than the surrounding aquifer material. Over the past decade, the use of iron-based PRBs has evolved from innovative to accepted standard practice for the containment and treatment of a variety of groundwater contaminants. Bench-scale studies using nanoscale, zero-valent iron PRBs have successfully degraded NDMA. However, the literature search that was conducted for this report indicated no cases where NDMA had been successfully treated by a field-tested, zero-valent iron PRB system. Alternative non-iron-based reactive materials are now being researched and deployed in the United States and abroad. One such potential material, zeolite, is discussed below.

Zeolites: Zeolites have been investigated with respect to their ability to both sorb and degrade nitrosamine compounds. The majority of this research has focused on the use of zeolites to capture and degrade cigarette smoke (e.g., Ma et al., 2000; Xu et al., 2004), where metal-modified zeolites have been shown to facilitate the decomposition of nitrosamines. A limited number of experimental studies to examine the sorption of nitrosamines (including NDMA) from the aqueous phase at room temperature also have been performed (Flemming et al., 1996; Zhu et al., 2001; Zhou et al., 2004). These studies have shown substantial nitrosamine sorption to select zeolites. In some cases, the zeolite also facilitated degradation of the nitrosamine compounds (Zhou et al., 2004).

Although the studies noted above provide some promising results regarding the use of zeolites for treating NDMA in groundwater, several critical questions remain to be answered before application of such technology can be considered for field implementation, or even field testing. First, groundwater was not used in the aqueous sorption experiments noted in the referenced studies. The aqueous geochemistry associated with natural groundwater, the presence of dissolved or colloidal organic materials, and the presence of any co-contaminants can have a substantial impact on the sorption of NDMA to the zeolites. Furthermore, the long-term effectiveness of the zeolites with respect to NDMA sorption/reaction have not been studied. The references studies were all based on short-term tests, whereas the potential application of this technology would demand long-term performance. In natural groundwater systems, sorption capacity of zeolites may be quickly diminished, rendering he zeolites treatment ineffective and rendering the technology far too cost prohibitive. Finally, NDMA requires treatment to low part-per-trillion levels in groundwater. To the best of our knowledge, no NDMA sorption studies on to zeolites have been performed at or near this range.

Thus, while initial laboratory research efforts show some promise with respect to the use of zeolites for treating NDMA, zeolite use for treating NDMA under field conditions remains unproven. Several basic questions remain unanswered, and considerable fundamental research is required before this technology can be considered as a potential groundwater remedy.

The report included as Appendix C also discussed the results of the implementation of PJKS-specific bench-scale and field demonstration NDMA treatment technologies. These results have been summarized in Section 5.0.

6.5 COSTS OF EXISTING OR PROPOSED REMEDIATION STRATEGY

As discussed above, no alternative to address the bedrock NDMA source areas was identified. Therefore, the remedial cost estimate is based on the containment alternative. The estimated cost for implementing just the boundary containment system component described in Section 6.4.3 is approximately $1,884,000 (Shaw, 2005f). The O&M costs for the system include long-term monitoring (LTM) of groundwater; monitoring of groundwater hydraulics; maintenance or replacement of mechanical systems such as pumps, and the nickel catalyst equipment; and O&M reporting required by the State. The O&M costs are estimated to be approximately $282,000 per year (Shaw, 2005f). It is also assumed that a review of the effectiveness of the system would be completed every 5 years at a cost of approximately $25,000 for each review. The total present worth cost for containment is approximately $6,288,000 and the non-discounted cost is $123,158,000 for 381 years (Shaw, 2005f). This time frame is a conservative estimate and assumes that the NDMA source areas will naturally attenuate resulting in a decrease in concentrations.

7.0 IDENTIFICATION OF ALTERNATIVES

As defined in the EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988b), general response actions are media-specific actions that satisfy the RAOs. For the purpose of this FFS, the medium of concern is TCE- and NDMA-contaminated groundwater.

The streamlined FFS approach will identify remedial alternatives for the seven source areas and for the alluvial groundwater migrating off the site. Existing information on remediation technologies and site characterization data will be used in the FFS to eliminate technology alternatives that cannot be effectively implemented at PJKS. Identification of treatment alternatives will be focused on process options that are known to be suitable for PJKS groundwater conditions. The traditional procedure of identifying general response actions, technologies, and process options through successive screening rounds in the feasibility study has instead been accomplished through previous pilot studies, bench scale studies, and research of alternative technologies. Various potential technologies, including chemical oxidation and aerobic co-metabolism were evaluated and screened out in the *Pilot Study Work Plan* (Shaw, 2003b). Site conditions have been fully characterized and several treatability studies and interim remedial actions have been completed resulting in only a limited number of alternatives that are practicable and realistic (EPA, 1990). These alternatives also fit the site conditions being addressed (as determined from the previously conducted remedial/site investigations), use the results from previous treatability studies and ICMs, and meet the established RAOs. A no action alternative is also included to provide a baseline for comparison purposes pursuant to 40 CFR 300.430(e)(6).

As part of the selected remedy, a TI waiver is warranted for NDMA in bedrock groundwater as discussed in Section 6.0, past studies and research indicate that restoration of groundwater to cleanup levels defined by the RAOs is not possible over all or portions of the contaminant plume(s) using currently available technologies. Two types of site conditions inhibit the ability to restore groundwater (EPA, 1993):

- Hydrogeologic constraints (e.g., aquifers with very low transmissivity, or aquifers with fractured bedrock or karst formations), and
- Contaminant-related constraints (e.g., the quantity, distribution, or properties of the contamination such as volume and depth of contamination, sorption potential, low volatility, low decay rate, or low solubility).

Examples of hydrogeologic and contaminant-related factors affecting the difficulty of remediating PJKS groundwater were discovered during the course of the extensive remedial investigations, groundwater monitoring, and pilot studies conducted at PJKS. Specifically, studies have shown that the hydrogeologic conditions at PJKS, coupled with contaminant constraints, make the remediation of NDMA in groundwater technically impracticable. For example, the U.S. Geological Survey conducted a study at Lariat Gulch where geophysical logs were obtained from six boreholes. The logs were run into two boreholes at the Fountain Formation at depths of about 65 and 570 ft. The other four logs were run through the Fountain Formation and into the underlying Precambrian Formation at depths of about 342 to 742 ft. The data from the logs shows few fractures in the boreholes and did not indicate a higher transmissivity in the contact zone between the Fountain and Precambrian Formations. Transmissivity for all fractures in each borehole were estimated to be less than two ft squared per day (Stone and Webster, 2002b). Therefore, the number of practicable treatment alternatives evaluated for PJKS groundwater is limited to those known to be effective for the treatment of TCE. However, while TCE can be treated, the ability to treat to CBSGs in the source areas in a time and cost efficient manner has not been achievable at many sites with similar hydrogeology. Instead, this FFS includes detailed evaluation of those technologies that can treat the groundwater to CBSGs at the point of compliance.

A remedial alternative that is a presumptive strategy for addressing groundwater contamination is the use of groundwater pump and treat systems to stop the flow of contaminants at the point of compliance. For the PJKS, this would require the installation of a groundwater pump and treat system in the alluvial groundwater at three different places on the PJKS site boundary.

As stated in Section 6.4 and 6.2.3, this alternative was discarded for the East Fork Brush Creek combined TCE/NDMA alluvial plume because it would have to work in perpetuity because it is not technically practicable to treat the source of NDMA. The use of a pump and treat system to halt the migration of the TCE contamination in the alluvial groundwater in the West Fork of Brush Creek and/or Lariat Gulch is a feasible alternative. However, based on information provided in the "Technical Memorandum Groundwater Interim Corrective Measure Performance Monitoring Report – 1st Quarter 2010 (Report #8) (Shaw, 2010d), the interim corrective measure biobarriers are creating an effective treatment zone in alluvial groundwater at the PJKS site. As noted below, it is anticipated that the insitu groundwater treatment interim measures will result in achievement of PRGs/MCSs throughout the alluvial groundwater plumes within a relatively short period of time. Since the use of an environmental covenant will prevent human exposure to the contaminated alluvial groundwater until PRGs/MCSs have been achieved, there is no need to create a groundwater pump and treat system in each of the three contaminated alluvial aquifers.

7.1 ALTERNATIVE 1 – NO ACTION

As required by the NCP, the No Action alternative was retained as a remedial alternative in this FFS report to serve as a baseline for comparison to other remedial alternatives. It does not include any active remediation or monitoring. No CERCLA action would be taken at the site to reduce or control potential risks.

7.2 ALTERNATIVE 2 – IN-SITU BIOREMEDIATION AND ENVIRONMENTAL COVENANTS

In situ technologies consist of introducing specific substrates or chemicals directly into the aquifer to enhance chemical or biological processes that degrade contaminants. Substrates are injected into the aquifer through groundwater wells, and the contaminant biodegradation occurs in the subsurface aquifer.

In-situ biodegradation of a variety of contaminants (including TCE) has been proven effective at many sites across the United States as well as at PJKS. In the natural environment however, this microbially mediated process may proceed slowly. To enhance the process for in-situ biodegradation of chlorinated solvents, microbial population growth is stimulated by artificially supplying a carbon source (substrate) such as carbohydrates (i.e., sugar) and, if necessary, other essential nutrients such as nitrogen and phosphorus. As the sugar degrades, metabolic acids are released. Microbes, in a process that releases hydrogen ions, metabolize the acids. The free hydrogen is used by other microbes to complete the reductive dechlorination process.

Common substrates for chlorinated solvent anaerobic biodegradation can include natural sugars such as molasses, manufactured compounds such as sodium lactate, or artificial sweeteners such as sorbitol. Compounds with low viscosity and high solubility, such as sodium lactate, move readily through fractured flow aquifers. These properties result in a shorter period of treatment in the subsurface; thus, sodium lactate requires more frequent periodic re-injection. Currently ICMs using in-situ biodegradation are in place at all seven groundwater source areas. ARD is being stimulated in the Fountain Formation and Precambrian aquifers at these source areas by injecting sodium lactate and a bioaugmentation culture (DHC) in specific groundwater monitoring wells in these areas. The purpose of ARD is to reduce contaminant concentrations in the source areas to levels that will ultimately achieve RAOs at the point of compliance. In addition to treating the source areas, ARD is being enhanced at the transition points (the point at which the groundwater moves from the bedrock to the alluvium) of the Fountain and Alluvial aquifers by the past construction of two biobarriers. One of the biobarriers originates from the SCA along a 300 foot linear alignment perpendicular to the East Fork of Brush Creek near the PJKS boundary, the other originating from the OTL/T-8A along a 150 foot linear alignment perpendicular to the West Fork of Brush Creek near the PJKS boundary. The biobarriers were constructed by injecting a mixture of EEO, sodium lactate solution, and DHC into direct-push boreholes.

Alternative 2 would consist of a continuing the ICMs, with modification to the system as necessary to implement the existing measures as a long-term solution. This alternative also includes costs (in year 30) for the abandonment of the groundwater monitoring well network. The treatment zone created by the interim corrective measure biobarriers are intended to last for several years without maintenance. Since the biobarriers were created using one-time injection boreholes that would require an extensive field effort to regenerate, the decision to regenerate the biobarriers will be made after evaluation of the performance of the bedrock source area treatment program over the Five-Year Review period.

In addition LUCs (in the form of Environmental Covenants) will be placed on the property. LUCs would protect human health and the environment by limiting exposure pathways. LUCs will consist of placing an Environmental Covenant on the PJKS site (PJKS Covenant) and the portion of Lockheed Martin’s property that is impacted by contaminated TCE and NDMA groundwater from PJKS (Lockheed Martin Covenant). The current owner of the PJKS property, Lockheed Martin, has agreed to the industrial use cleanup level for the PJKS site (included in the quit claim deed) and has committed to placing an Environmental Covenant, pursuant to Section 25-15-320 of the Colorado Revised Statutes (the Colorado Environment Covenant Law), on the property (Lockheed Martin, 2010). The industrial use restriction does not affect the groundwater; however, the Covenant will also include a provision that the groundwater at the site cannot be used, therefore, protecting human health and the environment by eliminating a potential exposure pathway. In addition to the Environmental Covenant of the PJKS property, Lockheed Martin has agreed to place an Environmental Covenant on the portion of their property that is impacted by contaminated groundwater from PJKS (Lockheed Martin, 2010). This Covenant will restrict the use of groundwater; therefore, protecting human health and the environment by eliminating a potential exposure pathway.

8.0 DETAILED ANALYSIS

This section includes the detailed analysis for the two alternatives selected for evaluation to address TCE-contaminated groundwater at PJKS. During the detailed analysis, the two alternatives, No Action and In-Situ Bioremediation, are assessed against nine evaluation criteria developed by the EPA and listed below. Assessments against two of the criteria relate directly to statutory findings that must ultimately be made in the ROD. Therefore, these are categorized as threshold criteria in that each alternative must meet them (EPA, 1988b). These two criteria are:

Overall Protection of Human Health and the Environment: Alternatives are evaluated to determine if they adequately protect human health and the environment, in both the short-term and the long-term, from unacceptable risks posed by contaminants present at the site by eliminating, reducing, or controlling exposures to levels established in the RAOs.

Compliance with ARARs: Alternatives are evaluated to determine how an alternative meets potential chemical-specific, location-specific, and action-specific ARARs. When a potential ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA is discussed.

The balancing criteria are used to make comparisons among those alternatives that satisfy the threshold criteria. The balancing criteria are:

Long-term Effectiveness and Permanence: Alternatives are assessed for the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated waste remaining at the site after response objectives have been met.

Reduction of Toxicity, Mobility, or Volume through Treatment: The degree to which an alternative uses recycling or treatment that reduces toxicity, mobility, or volume of contaminants is assessed. Factors that will be considered include the amount of hazardous contaminants that will be destroyed, treated, or recycled; the degree to which the treatment is irreversible; the type and quantity of residuals that will remain following treatment; and the degree to which treatment reduces the inherent hazards posed by principal threats at the site.

Short-term Effectiveness: The short-term impacts of alternatives and the short-term risks that might be posed to the community during implementation are considered. Also considered are the potential impacts on workers during remedial action and the effectiveness and reliability of protective measures; the potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and the length of time until protection is achieved.

Implementability: The ease or difficulty of implementing the alternatives is assessed by considering the technical and administrative feasibility of an alternative. The technical feasibility includes difficulties and unknowns associated with the construction and operation of an alternative, the reliability of the alternative, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy. The administrative factors considered in this assessment are the availability of services and material, including adequate off site treatment, storage, and disposal capacity and services. The availability of prospective alternatives, provisions to ensure any necessary additional resources, and the availability of necessary equipment and specialties are also considered.

Cost: The cost of each remedial alternative is evaluated in terms of capital costs, including both direct and indirect costs, annual O&M costs, and net present value of capital and O&M costs reflecting lifecycle costs. The cost analyses for Feasibility Studies are typically developed from a number of sources, including vendor estimates, and are accurate within a range of +50 to -30 percent. The cost analysis will be prepared pursuant to the format presented in the *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA, 2000) and the results will be presented in the FFS.

Modifying criteria are evaluated during the public comment period. Responses will be prepared for each of the comments and incorporated into the decision document. These criteria will not be evaluated during the FFS for PJKS. Regulator and community comments will be addressed in the decision document (i.e., the ROD). General descriptions of the two modifying criteria are presented below.

Regulator Acceptance: The technical and administrative issues and concerns CDPHE or EPA may have regarding each of the alternatives will be evaluated. An assessment of this criterion will be included in the decision document.

Community Acceptance: The issues and concerns the public may have regarding each of the alternatives will be evaluated. This assessment will not be completed until public comments on the proposed plan are received and will be addressed in the decision document.

8.1 ALTERNATIVE 1 – NO ACTION

The effectiveness of Alternative 1 is evaluated as follows.

8.1.1 Overall Protection of Human Health and the Environment

Under this alternative, the source area in groundwater would remain as it currently exists with no active effort to minimize contaminant levels or migration pathways. No efforts would be made to reduce any potential risks to human health and the environment. If no action is taken, the source areas will continue to contribute TCE into the bedrock and alluvial groundwater systems and degrade the shallow aquifer. Some attenuation or biodegradation may occur; however, the No Action Alternative does not include LTM of groundwater to assess the effects of any attenuation or biodegradation.

8.1.2 Compliance with ARARs

Alternative 1 is not compliant with the chemical-specific ARARs, specifically the CBSGs. CBSGs are established to be protective of human health and waters of the State of Colorado, and the No Action Alternative provides no means to determine whether the ARARs for groundwater have been met.

8.1.3 Long-Term Effectiveness and Permanence

Alternative 1 does not provide long-term effectiveness or permanent remedy for the groundwater contamination. This alternative does not manage or reduce risks associated with the groundwater contamination.

8.1.4 Reduction of Toxicity, Mobility, Volume through Treatment

The No Action Alternative would not provide an active treatment to reduce toxicity, mobility, or volume of contaminated groundwater at PJKS.

8.1.5 Short-Term Effectiveness

The No Action Alternative is protective of the community in the short-term because there is currently no groundwater pathway. However, workers who would encounter shallow groundwater during excavations are not protected. There are no environmental impacts to implement this alternative; however, the environmental quality of groundwater will continue to be degraded. Corrective action objectives may be achieved; however, a monitoring program is not included with this alternative and any natural biodegradation would not be measured. The length of time until protection is achieved is indefinite under this alternative.

8.1.6 Implementability

No technical or administrative feasibility concerns are associated with implementing Alternative 1 because no actions are being taken.

8.1.7 Cost

No capital costs are incurred with the No Action Alternative. However, the 5-Year Review process has been included as an operation and maintenance (O&M) cost and the corresponding present worth costs are incurred with the No Action Alternative and details presented in Appendix D.

Capital Cost:	$0
O&M Cost:	$66,168
Total Present Worth:	$24,000

Costs were developed using the Remedial Action Cost Engineering and Requirements™ (RACER™) software and the backup is provided in Appendix D.

8.2 ALTERNATIVE 2 – IN-SITU BIOREMEDIATION AND ENVIRONMENTAL COVENANTS

This technology offers several advantages over ex-situ groundwater treatment methods. Since treatment occurs in-situ, no groundwater pumping would be required, thus eliminating the ongoing need for an energy source. Equipment such as well pumps, filters, and air strippers would not be needed, eliminating the associated O&M costs, and active oversight of the system is reduced to routine compliance monitoring and preparation of O&M reports to satisfy State requirements, eliminating many worker safety issues. Additionally, technical and regulatory problems related to discharge requirements of effluents from pump and treat systems would be avoided.

8.2.1 Overall Protection of Human Health and the Environment

Alternative 2 is protective of human health and environment because it reduces the concentrations of COCs in groundwater source areas and eliminates potential exposure pathways. Controls would be in place to restrict the installation of shallow groundwater wells for potable drinking water until the groundwater is fully remediated below CBSGs.

8.2.2 Compliance with ARARs

Alternative 2 would comply with all potential ARARs

8.2.3 Long-Term Effectiveness and Permanence

This alternative will achieve long-term effectiveness by treating groundwater contaminants through a non-reversible process of biodegradation with no hazardous waste products or residuals. This corrective measure would be complete when LTM confirms the contaminant concentrations at the source areas have been depleted to meet remedial objectives or the reduction becomes asymptotic.

8.2.4 Reduction of Toxicity, Mobility, Volume through Treatment

This alternative would use in-situ biodegradation to irreversibly reduce the toxicity and volume of contaminated groundwater in the source areas by converting COCs to non-toxic by-products (i.e., ethene by-product from TCE degradation), and would satisfy the preference for treatment. The amount of contaminants treated within each source area will be site-specific.

8.2.5 Short-Term Effectiveness

Alternative 2 is protective of the community and workers because it decreases the toxicity of source areas contributing to the groundwater contamination and eliminates exposure pathways to the groundwater. There is limited direct risk to site workers to implement in-situ bioremediation (injecting a substrate into groundwater wells). However, if it is determined that additional wells need to be installed in order to expand the monitoring well or injection well network, there would be an increase to environmental impacts and worker risks from well installation. Potential impact to workers would be mitigated by using the proper PPE. The time to achieve significant source area reduction is currently estimated to be 3-5 years based on the D-1 ICM performance results. However, results at other source areas may differ. RAOs would be reached in a timely manner following the source area reduction.

8.2.6 Implementability

The required personnel and operation of Alternative 2 is technically feasible at PJKS. This alternative can be implemented using straightforward injection techniques. This technology has been successfully used at numerous sites across the country and at PJKS to remediate TCE. This technology is simple to operate and requires minimal maintenance. The climate, terrain, and seasonal changes routinely encountered at PJKS would not impact the implementability of Alternative 2.

The coordination of multiple offices or agencies would not be required to implement Alternative 2. This alternative would be implemented entirely on site and, as a result, would not require any off site permits. The equipment, materials, and resources required for this alternative are readily available and already in use at PJKS. The major components of the alternative are the substrate material and then the means to inject the substrate to groundwater (i.e., via pumps and an appropriate energy source). The personnel, groundwater sampling equipment, and laboratory services necessary to implement a LTM program are readily available and already in use at PJKS. If future injection wells are needed to be installed at source areas, the alternative can still be implemented using industry standard techniques that are readily available. Finally, the property owner, Lockheed Martin, has agreed to place LUCs on the property, in the form of an Environmental Covenant on the PJKS property (PJKS Covenant) and on their property (Lockheed Martin Covenant) that is impacted by groundwater contamination from PJKS.

8.2.7 **Cost**

Capital costs, O&M costs, or present worth costs estimated for Alternative 2 are included in Appendix D.

Capital Cost:	$1,067,353
O&M Cost:	$1,028,039
Total Present Worth:	$611,000

Costs were developed using the RACER™ software and the backup is provided in Appendix D.

9.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The comparative analysis of the alternatives identifies the advantages and disadvantages of each alternative relative to one another to allow the decision-makers to identify key tradeoffs among the alternative. The relative performance of each alternative is evaluated in relation to each of the seven evaluation criteria used in the detailed analysis. Again, regulator acceptance and community acceptance will be assessed in the decision document.

The two alternatives identified for TCE-contaminated groundwater at PJKS include No Action (Alternative 1) and In-Situ Bioremediation with Environmental Covenants (Alternative 2).

9.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternative 1 does not provide for overall protection of human health and the environment as there will be no decrease in contaminants in the source areas (other than potential natural biodegradation). Alternative 2 is protective of human health and environment because it reduces the concentrations of COCs in groundwater source areas and eliminates exposure pathways.

9.2 COMPLIANCE WITH ARARS

Alternative 1 is not compliant with the chemical-specific ARARs, specifically the CBSGs. Alternative 2 would comply with all potential ARARs.

9.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Alternative 1 does not provide long-term effectiveness or permanent remedy for the groundwater contamination. Alternative 2 will achieve long-term effectiveness by treating groundwater contaminants through a non-reversible process of biodegradation with no waste products or residuals.

9.4 REDUCTION OF TOXICITY, MOBILITY, VOLUME THROUGH TREATMENT

Alternative 1 does not reduce toxicity, mobility, or volume of contaminated groundwater at PJKS. Alternative 2 uses in-situ biodegradation to accelerate contaminant removal and irreversibly reduce the toxicity and volume of contaminated groundwater by converting COCs to non-toxic by-products (i.e., ethene by-product from TCE degradation).

9.5 SHORT-TERM EFFECTIVENESS

There are no environmental impacts to implement Alternative 1. If there are no changes made to the ICM system at PJKS, there are also no environmental impacts to implement Alternative 2. However, if it is determined that additional wells need to be installed in order to expand the monitoring well or injection well network, there would be a slight increase to environmental impacts and worker risks from well installation or other monitoring activities. Alternative 1 is not protective of the community and is not protective of workers who would encounter shallow groundwater during excavations. Alternative 2 is protective of the community and workers because it decreases the toxicity of source areas contributing to the groundwater contamination.

9.6 IMPLEMENTABILITY

No technical or administrative feasibility concerns are associated with implementing Alternative 1 because no actions are being taken. With the exception of LUCs, Alternative 2 has already been implemented at PJKS. The property owner, Lockheed Martin, has agreed to place an Environmental Covenant on the PJKS property (PJKS Covenant) and the portion of Lockheed Martin property (Lockheed Martin Covenant) that is impacted by contaminated groundwater from PJKS.

9.7 COST

Nominal costs associated with the 5-year review process are incurred with Alternative 1. Alternative 2 is more expensive then Alternative 1, but is overall more protective to human health by controlling and restricting access as well as treating the source to groundwater contamination.

10.0 RECOMMENDED ALTERNATIVES

Alternative 2 (In-situ Bioremediation with Environmental Covenants) is recommended for the remediation of TCE-contaminated groundwater and protection of current and future land use from TCE and NDMA-impacted groundwater. A TI waiver is sought for NDMA in bedrock groundwater. As discussed in Section 7.2.2, in-situ bioremediation has already been implemented at the site as part of ICMs. Performance monitoring results indicate that the ARD is successfully treating TCE within the groundwater. This FFS recommends continuing to operate and monitor the existing bioremediation system at this site. Details of this system are included in Section 7.2.2. Currently, there is a single final injection round proposed to upgrade the system. Periodic monitoring will continue to evaluate the performance. Currently, the USAF is looking for ways to streamline the sampling and to collect more timely and specific information.

LUCs would protect human health and the environment by limiting exposure pathways and reducing risk of future exposures. LUCs will consist of placing an Environmental Covenant on the PJKS site. The current owner of the PJKS property, Lockheed Martin, has agreed to the industrial use cleanup level for the site (included in the quit claim deed) and has committed to placing an Environmental Covenant, pursuant to Section 25-15-320 of the Colorado Revised Statutes (the Colorado Environment Covenant Law), on the property. The PJKS Covenant will specify that all of the property that comprises the PJKS site will only be used for industrial purposes and will be placed on the property soon after the final corrective measure for the entire facility has been selected and approved. The survey coordinates for the locations where these restrictions will apply, along with detailed language for the restrictions, will be specified in the final ROD for PJKS.

11.0 REFERENCES

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TABLES

TABLE 1
SUMMARY OF ICM ACTIVITIES AND RECOMMENDATIONS FOR SOIL SWMUs
FORMER USAF PLANT PJKS, WATERTON CANYON, CO

SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 4 Open Burning/Open Detonation Unit	Remedial investigation and early action complete.	6	Unrestricted Site Closure	August 23, 2000 CDPHE letter	OT009
SWMU 5 Waste Propellant Storage Unit	Remedial investigation and early action complete.	1	Unrestricted Site Closure	August 7, 2000 CDPHE letter	T28/6
SWMU 6 Decontamination Trailer Tank Spill Area	Remedial investigation and early action complete.	2	Unrestricted Site Closure	June 8, 2001 CDPHE letter	ST015
SWMU 7 Leak Detection Line Drain (BC-79) at T-6033	Remedial investigation complete.	1	Unrestricted Site Closure	September 7, 2001 CDPHE letter	SS011
SWMU 8 T-8A Surface Impoundment	Remedial investigation complete; O&M Plan (originally called Post-Closure Care Work Plan) in place.	3	Restricted Site Closure and Limited Cover. Existing Surface Impoundment concrete liner structure is the limited cover over PCBs in soils.	December 6, 2004 CDPHE letter	WP001
SWMU 9 D-1 Landfill	Remedial investigation and ICM activities complete in 2009.	3	Unrestricted Site Closure	December 17, 2009 CDPHE letter	LF004
SWMU 10 Upper (LOX) Volcano	Remedial investigation and early action complete.	2	Unrestricted Site Closure	January 13, 2003 CDPHE letter	SS018
SWMU 11 Lower (Fuel) Volcano	Remedial investigation and early action complete.	2	Unrestricted Site Closure	January 13, 2003 CDPHE letter	SS019
SWMU 12 Valve Shop Solvent Storage Area	ICM activities, including excavation and off-site disposal of contaminated soil, completed in September 2005; O&M Plan in place.	2	Restricted Site Closure and Limited Cover. RAOs have been met with the exception of PCB contaminated soil greater at one area in Valve Area 1, which has a limited cover installed (i.e. asphalt).	August 2, 2006 CDPHE letter	SS017
SWMU 13 Valve Shop Process Water Drain	ICM activities, including excavation and off-site disposal of contaminated soil, completed in September 2005.	2	Restricted Site Closure. RAOs have been met.	August 2, 2006 CDPHE letter	SS044

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SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 14 T-31 Chemical Treatment Facility	Remedial investigation and ICM activities complete in 2009.	3	Unrestricted Site Closure	December 17, 2009 CDPHE letter	SS065
SWMU 15 T-8 Drainage Flumes	ICM activities, including excavation and off-site disposal of contaminated soil, completed in October 2005.	3	Restricted Site Closure. RAOs have been met.	August 2, 2006 CDPHE letter	SD008
SWMU 16 D-1 Test Stand	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	SS053
SWMU 17 D-2 Test Stand	ICM activities, including excavation and off-site disposal of contaminated soil, completed in October 2005.	3	Restricted Site Closure. RAOs have been met.	August 2, 2006 CDPHE letter	SS054
SWMU 18 D-1 Fuel Storage Area	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs or Tier II Residential SROs.	3	Unrestricted Site Closure.	June 23, 2005 CDPHE letter	SS058
SWMU 19 D-2 Fuel Storage Area	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	SS059
SWMU 20 Acid Neutralization Pit	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	ST032
SWMU 21 D-3 Test Stand	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	SS055

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SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 22 D-4 Test Stand	ICM activities, including excavation and off-site disposal of contaminated soil, completed in October 2005.	3	Restricted Site Closure. RAOs have been met.	August 2, 2006 CDPHE letter	SS056
SWMU 23 T-9 Gas Storage Area	Additional soil investigation did not confirm previously reported elevated pesticide concentrations. No COC concentrations exceeded the Tier 2 Residential SROs.	3	Unrestricted Site Closure.	June 23, 2005 CDPHE letter	ST014
SWMU 24 D-4 Fuel Storage Area	The additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	SS020
SWMU 25 D-3 Fuel Holding Pond	The additional soil investigation found no evidence that COC concentrations exceeded the RAOs. Therefore, no additional combined soil activities were required at this SWMU.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	SS036
SWMU 26 D-4 Fuel Holding Pond	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs or the Tier 2 Residential SROs.	3	Unrestricted Site Closure.	June 23, 2005 CDPHE letter	ST031
SWMU 27 Riprap Area North of T-8A Containment Pond	Remedial investigation complete.	3	No Further Action	April 3, 2003 CDPHE letter	LF012
SWMU 28 Riprap Area West of Central Support Building T-17	Remedial investigation complete.	2	No Further Action	August 29, 2002 CDPHE letter	SS037

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SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 29 Systems and Components General Area (SCA)	ICM activities, including excavation and off-site disposal of contaminated soil, completed in September 2005; O&M Plan in place.	1	Restricted Site Closure and Limited Cover. The ICM activities have achieved the PJKS RAOs with the exception of PCB contaminated soil greater than the RAOs at one area in SCA Area 1 and at one area in SCA Area 2, which have limited covers installed (i.e., concrete).	August 2, 2006 CDPHE letter	SS006
SWMU 30 Systems Fuel Vault French Drain (BC-58) at T-6032	Remedial investigation complete.	1	No Further Action	November 4, 2003 CDPHE letter	SS047
SWMU 31 Engineering Propulsion Laboratory (EPL) General Area	ICM activities, including excavation and off-site disposal of contaminated soil, completed in October 2005; O&M Plan in place.	2	Restricted Site Closure and Limited Cover. The ICM activities have achieved the PJKS RAOs with the exception of PCB contaminated soil greater than the RAOs near Building T-23, which has a limited cover installed (i.e., concrete).	August 2, 2006 CDPHE letter	SS002
SWMU 32 Valve Shop Acid Tank Area	Additional soil investigation found no evidence that COC concentrations exceeded the Tier 2 Residential SROs.	2	Unrestricted Site Closure.	June 23, 2005 CDPHE letter	ST030
SWMU 33 OTL Oil Leak Area	Additional groundwater investigation found no evidence that the analytical results exceeded the RAOs or STG exceedances in soil impact groundwater downgradient of the SWMU.	6	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	ST035

TABLE 1
SUMMARY OF ICM ACTIVITIES AND RECOMMENDATIONS FOR SOIL SWMUs
FORMER USAF PLANT PJKS, WATERTON CANYON, CO

SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 34 T-13A Deluge Tank Area	Additional soil investigation found no evidence that COC concentrations exceeded the RAOs.	3	Restricted Site Closure. RAOs have been met.	June 23, 2005 CDPHE letter	ST064
SWMU 35 D-1 Septic Tank and Leach Field	Additional soil investigation found no evidence that COC concentrations exceeded the Tier 2 Residential SROs.	3	Unrestricted Site Closure.	June 23, 2005 CDPHE letter	SS057
SWMU 36 System Oxidizer Tank Vault French Drain (BC-61) at T-6031	Remedial investigation complete.	1	No Further Action	November 4, 2003 CDPHE letter	ST045
SWMU 37 Components Cavitette and Leachfield: T-27	Remedial investigation complete.	1	No Further Action	April 22, 2003 CDPHE letter	SS046
SWMU 38 Systems Cavitette and Leachfield: T-28	Remedial investigation complete.	1	No Further Action	April 22, 2003 CDPHE letter	SS051
SWMU 39 T-6 Blockhouse Cavitette and Leachfield	Remedial investigation complete.	2	No Further Action	April 22, 2003 CDPHE letter	SS040
SWMU 40 Field and Central Support Septic Tank and Leachfield: T-17, T-23	Remedial investigation complete.	6	No Further Action	April 22, 2003 CDPHE letter	SS041
SWMU 41 Ordnance Testing Laboratory Cavitette and Leachfield: T-26	Remedial investigation complete.	6	No Further Action	April 22, 2003 CDPHE letter	SS052
SWMU 42 T-20A Compressor House	Remedial investigation complete.	2	No Further Action	February 22, 2003 CDPHE letter	SS002
SWMU 43 T-28D Equipment Room Floor Drain	Remedial investigation complete.	1	No Further Action	November 29, 2001 CDPHE letter	SS048

TABLE 1
SUMMARY OF ICM ACTIVITIES AND RECOMMENDATIONS FOR SOIL SWMUs
FORMER USAF PLANT PJKS, WATERTON CANYON, CO

SWMU Name	Summary of Activities	Operable Unit	Status[1]	Documentation[2]	IRP/SRI Number
SWMU 44 Central Support Storage Area: T-17	Remedial investigation complete.	2	No Further Action	November 29, 2001 CDPHE letter	SS042
SWMU 45 Pump Pit #2	Remedial investigation complete.	2	No Further Action	November 29, 2001 CDPHE letter	SS043
SWMU 46 Missile Storage Building Drain: T-42	Remedial investigation complete.	6	No Further Action	November 29, 2001 CDPHE letter	SS038
SWMU 47 Tank MM7, Building T-23	Remedial investigation complete.	2	No Further Action	February 22, 2003 CDPHE letter	ST005
SWMU 48 Tank 005, Building T-A	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST023
SWMU 49 Tank MM4, Building T-6	Remedial investigation complete.	2	No Further Action	October 24, 2001 CDPHE letter	ST013
SWMU 50 Tank MM6 Building T-A	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST010
SWMU 51 Tank MM8, Building T-B	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST024
SWMU 52 Tank MM9	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST025
SWMU 53 Tank MM11, Building T-2A	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST016
SWMU 54 Tank MM12, Building T-2B	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST026
SWMU 55 Tank MM13, Test Stand D-3	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST027
SWMU 56 Tank MM14, Test Stand D-4	Remedial investigation complete.	3	No Further Action	January 7, 2003 CDPHE letter	ST028

Notes:
[1] - The RAOs for soil are based on Tier 2 SRO values. Tier 2 SRO and STG values were calculated for PJKS using guidance from the Proposed Soil Remediation Objectives Policy Document (State of Colorado, 1997). The quit claim deed transferring PJKS from the USAF to Lockheed Martin restricts the land use to non-residential. As a result, Tier 2 SRO values were calculated based on the risk to human health using an industrial land use scenario, which provides more conservative RAO values than the commercial land use scenario. Therefore, sites where concentrations meet the RAOs still require restricted closure to limit the area to industrial use.
[2] – Documentation letters are found in Appendix A.

TABLE 1
SUMMARY OF ICM ACTIVITIES AND RECOMMENDATIONS FOR SOIL SWMUs
FORMER USAF PLANT PJKS, WATERTON CANYON, CO

SWMU – Soil Waste Management Unit
ICM – Interim Corrective Measures
RAO – Remedial Action Objective
COC – Contaminants of Concern
SRO – Soil Remediation Objectives
PCB – Polychlorinated Biphenyls
STG – Soil to Groundwater
CDPHE – Colorado Department of Public Health and the Environment

TABLE 2
2009 SPRING AND FALL PROGRAM GROUNDWATER ELEVATIONS

Well ID	Formation	Monitoring Point Elevation (ft above MSL)	Spring 2009 GW Elevation (ft above MSL)	Fall 2009 GW Elevation (ft above MSL)	Difference (in ft) between Spring & Fall 2009 GW Elevations
1-M3D	F	6130.95	-	6077.23	-
1-M5B	F	6077.69	6047.49	6050.13	2.64
1-M6B	F	6071.20	-	6043.31	-
1-M7B	F	6053.96	-	6025.33	-
1-M7D	F	6053.90	-	6021.14	-
3-M06B	P	6240.90	-	6177.26	-
3-M09B	P	6382.82	-	6307.53	-
4-M2B	F	6054.47	-	6036.43	-
5-M04	A	5855.62	-	5834.17	-
5-M05	P	6214.66	-	6177.76	-
5-M05B	P	6213.65	-	6189.85	-
5-M06B	F	6210.71	-	6156.89	-
5-M07	P	6204.66	-	6184.97	-
5-M15	A	6067.65	-	6053.12	-
5-M15B	P	6068.35	-	6051.91	-
5-M24	A	5857.76	-	5854.54	-
5-M32	A	6077.96	-	6047.90	-
5-M35B	P	6297.29	-	6267.65	-
6-M2	F	6002.39	-	5979.65	-
6-M3I	F	6013.65	-	5995.34	-
AOC2-M3	A	6163.75	-	6141.93	-
BCMW-016-P	P	6382.59	6356.43	6346.34	10.09
BCMW-017-P	P	6381.88	6322.22	6317.24	4.98
GM87	A	5888.42	-	5861.53	-
GM91B	F	5891.93	-	5883.80	-
I-1-MW1B	F	5979.11	5970.15	5968.71	1.44
I-1-M2B	F	5972.89	-	5954.00	-
I-3-M5	A	5925.95	-	5904.93	-
I-3-M7B	F	5895.95	-	5876.02	-
I-3-M8B	F	5925.77	-	5911.60	-
I-7-M3	A	5945.73	-	5924.55	-
I-7-M4	A	5936.80	-	5922.66	-
I-7-M4B	F	5936.83	-	5921.88	-
I-7-M6B	F	5965.47	-	5942.11	-
I-7-M13	A	6073.49	-	6055.79	-
I-7-M14	A	5999.67	-	5969.04	-
I-7-M14B	F	5999.31	-	5969.45	-
I-7-M17	A	5911.49	-	5899.21	-
II-1-M6	A	6027.18	-	6005.37	-
II-1-M8A	A	6059.48	-	6042.60	-
II-1-M12B	F	6022.84	-	5997.08	-
II-1-M14B	F	6053.09	-	6035.71	-
III-1-M4	A	6061.46	-	6042.96	-
III-1-M4D	F	6064.20	-	6043.25	-
III-1-M4L	F	6063.72	-	6044.57	-
III-1-M7D	F	6066.68	-	6026.69	-
III-1-M7I	F	6067.71	-	6044.82	-

TABLE 2
2009 SPRING AND FALL PROGRAM GROUNDWATER ELEVATIONS

Well ID	Formation	Monitoring Point Elevation (ft above MSL)	Spring 2009 GW Elevation (ft above MSL)	Fall 2009 GW Elevation (ft above MSL)	Difference (in ft) between Spring & Fall 2009 GW Elevations
III-1-M8	A	5972.80	-	5950.24	-
III-1-M8B	F	5972.69	-	5956.06	-
III-1-M10B	F	6026.45	6012.18	6012.06	0.12
III-2-M2	A	5977.46	-	5960.83	-
III-2-M2B	F	5978.42	-	5962.98	-
III-2-M5	A	5955.57	-	5932.13	-
IV-1-MW4	A	6147.49	-	6125.07	-
IV-1-MW4B	A	6147.38	-	6124.94	-
IV-1-MW6	A	6126.77	-	6116.43	-
IV-1-MW6B	P	6127.90	-	6120.52	-
LGMW-011-A	A	5860.92	-	5836.62	-
LGMW-015-A	A	6054.95	-	6030.79	-
LGMW-018-P	P	6486.30	-	6410.08	-
LGMW-019-P	P	6445.82	-	6314.28	-

Alluvial average difference between spring and fall:	N/A
Fountain average difference between spring and fall:	1.40
Precambrian average difference between spring and fall:	7.54

Notes:
ft = feet
GW = groundwater
ID = identification
MSL = mean sea level
A = Alluvial
F = Fountain
P = Precambrian

TABLE 3
POTENTIAL CHEMICAL-SPECIFIC ARARs, CRITERIA, ADVISORIES, AND GUIDANCE

Standard, Requirement, Criteria, or Limitation	Citation	Status	Description
		Federal	
Clean Water Act			
Water Quality Standards	40 CFR 131	Relevant and Appropriate	Establishes non-enforceable criteria for the protection of human health and/or aquatic organisms.
Resource Conservation and Recovery Act			
Alternative Concentration Limits	40 CFR 264, Subpart F	Relevant and Appropriate	Allows for the setting of alternative concentration limits if the hazardous constituents in groundwater will not pose a danger to human health and the environment.
		State of Colorado	
Colorado Department of Public Health And Environment			
Colorado Basic Standard for Groundwater	5 CCR 1002-41	Applicable	The preferred alternative uses the statewide health-based standards for waters of the state for RAOs.
Colorado Rules and Regulations Pertaining to Hazardous Waste	6 CCR 1007, Part 261	Relevant and Appropriate	Establishes listing requirements of hazardous wastes.
Colorado Primary Drinking Water Regulations	5 CCR 1003-1	Relevant and Appropriate	Establishes drinking water standards that apply to specific contaminants and have been determined to have an adverse effect on human health.
		To Be Considered	
Requirements for the Analysis of NDMA in PJKS Groundwater	CDPHE, 2008	TBC	Approves new analytical method with lower method detection limits and practical quantitation limits for the analysis of NDMA at PJKS

Notes:
CCR = Colorado Code of Regulations
NDMA = n-nitrosodimethylamine
TBC = To Be Considered
CDPHE = Colorado Department of Public Health and Environment
PJKS = Former United States Air Force Plant PJKS
CFR = Code of Federal Regulations
RAO = remedial action objective

CDPHE. 2008. Letter regarding Requirements for the Analysis of N-Nitrosodimethylamine (NDMA) in Former Air Force Plant PJKS Groundwater, Compliance Order on Consent 98-10-08-01, U.S. Air Force Plant PJKS: CO7570090038. From David Walker, State Project Manager. To Corey Lam, Environmental Restoration Manager, U.S. Air Force Aeronautical Systems Center. May 19.

TABLE 4
POTENTIAL LOCATION-SPECIFIC ARARs, CRITERIA, ADVISORIES, AND GUIDANCE

Standard, Requirement, Criteria, or Limitation	Citation	Status	Description
Federal			
National Archaeological and Historical Preservation Act	16 USC 469; 36 CFR Part 65	Relevant and Appropriate	This act requires that any artifacts present at the site are recovered and preserved. Compliance with the act is achieved if a mitigation plan is prepared and implemented, should cultural resources be threatened.
National Historic Preservation Act	16 USC 470	Relevant and Appropriate	Authorizes the Secretary of the Interior to expand and maintain a National Register of Historic Places.
Endangered Species Act	16 USC 1531	Relevant and Appropriate	Protection of endangered species and their habitats. No threatened and endangered species are present at PJKS; if a threatened or endangered species were to be encountered, then requirements of the act could be applicable.
State of Colorado			
Colorado Non-Game, Endangered, or Threatened Species Conservation Act	CRS 33-2-101	Relevant and Appropriate	Regulates construction that jeopardizes critical habitat or designated species. May be applicable if state-designated species were to be encountered.
Historical, Prehistorical, and Archaeological Resources Act	8 CCR 1504-7	Relevant and Appropriate	Coordinates, encourages, and preserves the full understanding of Colorado's archaeological and paleontological resources for the benefit of Colorado's citizens.
Colorado Register of Historic Places Act	CRS 24-80.1-101 to 108	Relevant and Appropriate	Establishes that sites and structures possessing historical significance are cultural resources of the state and should be preserved.

Notes:
CCR = Colorado Code of Regulations
CFR = Code of Federal Regulations
CRS = Colorado Revised Statute
SWMU = solid waste management unit
USC = United States Code

TABLE 5
POTENTIAL ACTION-SPECIFIC ARARs, CRITERIA, ADVISORIES, AND GUIDANCE

Standard, Requirement, Criteria, or Limitation	Action	Citation	Status	Description
Federal				
Resource Conservation and Recovery Act				
Corrective Action	Remediation	40 CFR 264	Applicable	The preferred alternative will follow corrective action requirements and remedial actions.
Safe Drinking Water Act				
Underground Injection Control	Fluid injection	40 CFR Parts 9, 144, 145, 146	Applicable	The preferred alternative will require injection of substrates and microbes (as fluids) for aquifer remediation into the groundwater via injection wells.
State of Colorado				
Colorado Department of Public Health and Environment				
Colorado Water Well Construction Rule 2	Well abandonment	2 CCR 402-2 Rule 16	Applicable	The preferred alternative will require well abandonment as part of the corrective action.
Colorado Environmental Covenant Act	Land use controls	CRS 25-15-317 through 327	Applicable	The preferred alternative will require an environmental covenant for the remedy that is not designed to achieve unrestricted use upon completion of remedy.
To Be Considered				
Corrective Action Guidance Document	Cleanup guidance	CDPHE, 2002	TBC	The cleanup approach for PJKS will follow the framework set out in the document.
Compliance Order on Consent	PJKS Cleanup requirements	State of Colorado, 1998	TBC	Both CERCLA and RCRA regulations are appropriate for PJKS; this order sets CDPHE as the lead regulator.

TABLE 5 (CONTINUED)
POTENTIAL ACTION-SPECIFIC ARARS, CRITERIA, ADVISORIES, AND GUIDANCE

Standard, Requirement, Criteria, or Limitation	Action	Citation	Status	Description
To Be Considered cont.				
Clarification Letter	Clean up of PJKS off-site groundwater plumes	CDPHE, 2010	TBC	This letter requires the Air Force to finalize outstanding cleanup obligations, specifically how the PJKS and Lockheed Martin will resolve off-site groundwater issues.
Memorandum of Agreement	PJKS Environmental Covenant agreement	Lockheed Martin, 2010	TBC	This agreement between the Air Force and Lockheed Martin specifies the use of Environmental Covenants to be protective of future land use at PJKS and any portion of Lockheed Martin with PJKS groundwater plumes.

Notes:
CCR = Colorado Code of Regulations
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CRS = Colorado Revised Statute
RCRA = Resource Conservation and Recovery Act
USC = United States Code
CDPHE = Colorado Department of Public Health and Environment
CFR = Code of Federal Regulations
PJKS = Former Air Force Plant PJKS
TBC = To Be Considered

Colorado Department of Public Health and Environment. (CDPHE). 2002. *Corrective Action Guidance Document.* Hazardous Materials and Waste Management Division. May.

CDPHE. 2010. Letter regarding Requirements for Submittal of the Feasibility Study Work Plan and the Feasibility Study Report for Operable Unit Nos. 4 and 5/Solid Waste Management Units Nos. 1, 2 and 3, Compliance Order on Consent 98-10-08-01. From David Walker, State Project Manager and David Rathke, EPA Project Manager. To Corey Lam, Environmental Restoration Manager, U.S. Air Force Aeronautical Systems Center. January 25.

Lockheed Martin Corporation, Space Systems Company. 2010. Memorandum of Agreement between Lockheed Martin Corporation and the Department of the Air Force stating that the Air Force will perform future corrective actions to address contaminants on and from the Former Air Force Plant PJKS. Signed by Lockheed Martin Corporation and United States Air Force. March 15.

State of Colorado. 1998. *Compliance Order on Consent in the Matter of Air Force Plant PJKS Site, No. 98-10-08-01*. Effective December 29.

TABLE 6
REMEDIAL ACTION OBJECTIVES SUMMARY

<table>
<tr><th>Medium</th><th>Contaminant</th><th>Exposure Route</th><th>To Be Achieved Upon Signing of the ROD</th><th>To Be Achieved at Some Time in the Future (All Initial RAO's Still Apply)</th><th colspan="2">PRG/MCS µg/L</th></tr>
<tr><td>Bedrock Groundwater

TCE Only Source Areas</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>Ingestion, Direct Contact</td><td>Prevent ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)</td><td>• Reduce TCE and daughter products to meet CBSG or:
• Reduce TCE and daughter products to meet CBSG's at Point of Compliance or:
• Reduce TCE and daughter products to asymptotic levels</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>5
5
70
100
2</td></tr>
<tr><td rowspan="2">Bedrock Groundwater

NDMA & TCE Source Areas</td><td rowspan="2">NDMA
&
TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td rowspan="2">Ingestion, Direct Contact</td><td>Prevent ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)</td><td rowspan="2">• Reduce TCE and daughter products to meet CBSG or:
• Reduce TCE and daughter products to meet CBSG's at Point of Compliance or:
• Reduce TCE and daughter products to asymptotic levels</td><td>NDMA</td><td>0.05</td></tr>
<tr><td>Technical Impracticability for NDMA in Bedrock Source Areas</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>5
5
70
100
2</td></tr>
<tr><td rowspan="2">Alluvial Groundwater

Onsite</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>Ingestion, Direct Contact, Inhalation</td><td>Prevent inhalation exposure, ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)</td><td>• Reduce TCE and daughter products to meet CBSG or:
• Reduce TCE and daughter products to meet CBSG's at Point of Compliance or:
• Reduce TCE and daughter products to asymptotic levels</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>5
5
70
100
2</td></tr>
<tr><td>NDMA</td><td>Ingestion, Direct Contact</td><td>Prevent ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)</td><td>--</td><td>NDMA</td><td>0.05</td></tr>
<tr><td>Alluvial Groundwater

Point of Compliance</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>Ingestion, Direct Contact, Inhalation</td><td>Prevent inhalation exposure, ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)</td><td>• Reduce TCE and daughter products to meet CBSG or:
• Reduce TCE and daughter products to meet CBSG's at Point of Compliance or</td><td>TCE
1,1-DCE
cis-1,2-DCE
trans1,2DCE
VC</td><td>5
5
70
100
2</td></tr>
</table>

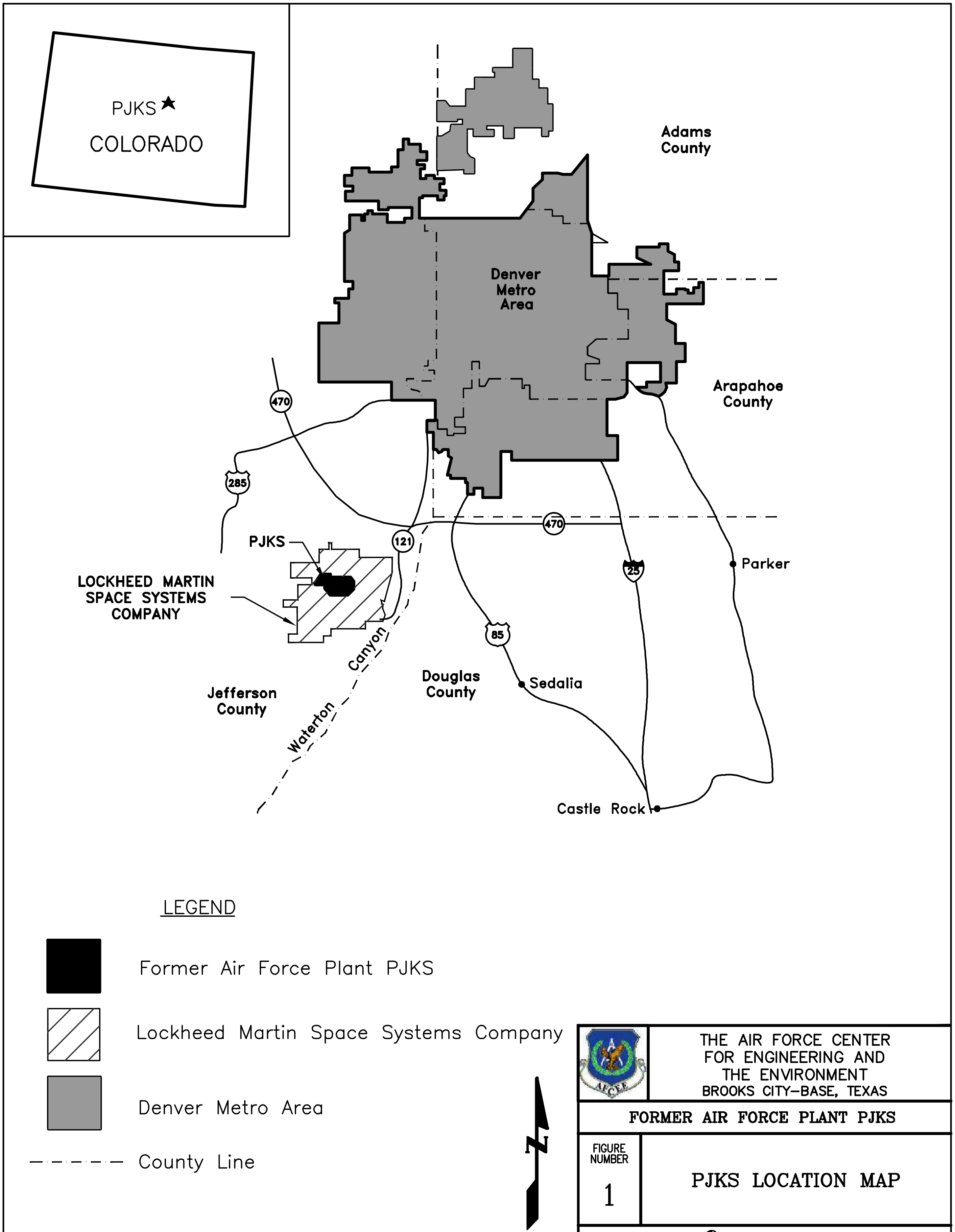
TABLE 6
REMEDIAL ACTION OBJECTIVES SUMMARY

Medium	Contaminant	Exposure Route	To Be Achieved Upon Signing of the ROD	To Be Achieved at Some Time in the Future (All Initial RAO's Still Apply)	PRG/MCS µg/L	
Alluvial Groundwater Point of Compliance	NDMA	Ingestion, Direct Contact	Prevent ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)	--	NDMA	0.05
Alluvial Groundwater Off-site PJKS	TCE 1,1-DCE cis-1,2-DCE trans1,2DCE VC	Ingestion, Direct Contact, Inhalation	Prevent inhalation exposure, ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)	• Reduce TCE and daughter products to meet CBSG	TCE 1,1-DCE cis-1,2-DCE trans1,2DCE VC	5 5 70 100 2
	NDMA	Ingestion, Direct Contact	Prevent ingestion and direct contact via Environmental Covenant and other Land Use Controls (e.g., LMSSC Black Zone Map)	--	NDMA	0.05

** The Colorado State Standard for NDMA is 0.00069 µg/L. Colorado regulations state that if a standard is below the practical quantitation limit (PQL) of the approved analytical method, the PQL is the enforcement standard. The PQL for the currently approved method is 0.05 µg/L.

DCE = dichloroethene
MCS = media cleanup standards
NDMA = n-nitrosodimethylamine
PRG = preliminary remediation goal
µg/L = micrograms/liter
ROD = Record of Decision
TCE = trichloroethene
VC = vinyl chloride

FIGURES



THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 1

PJKS LOCATION MAP

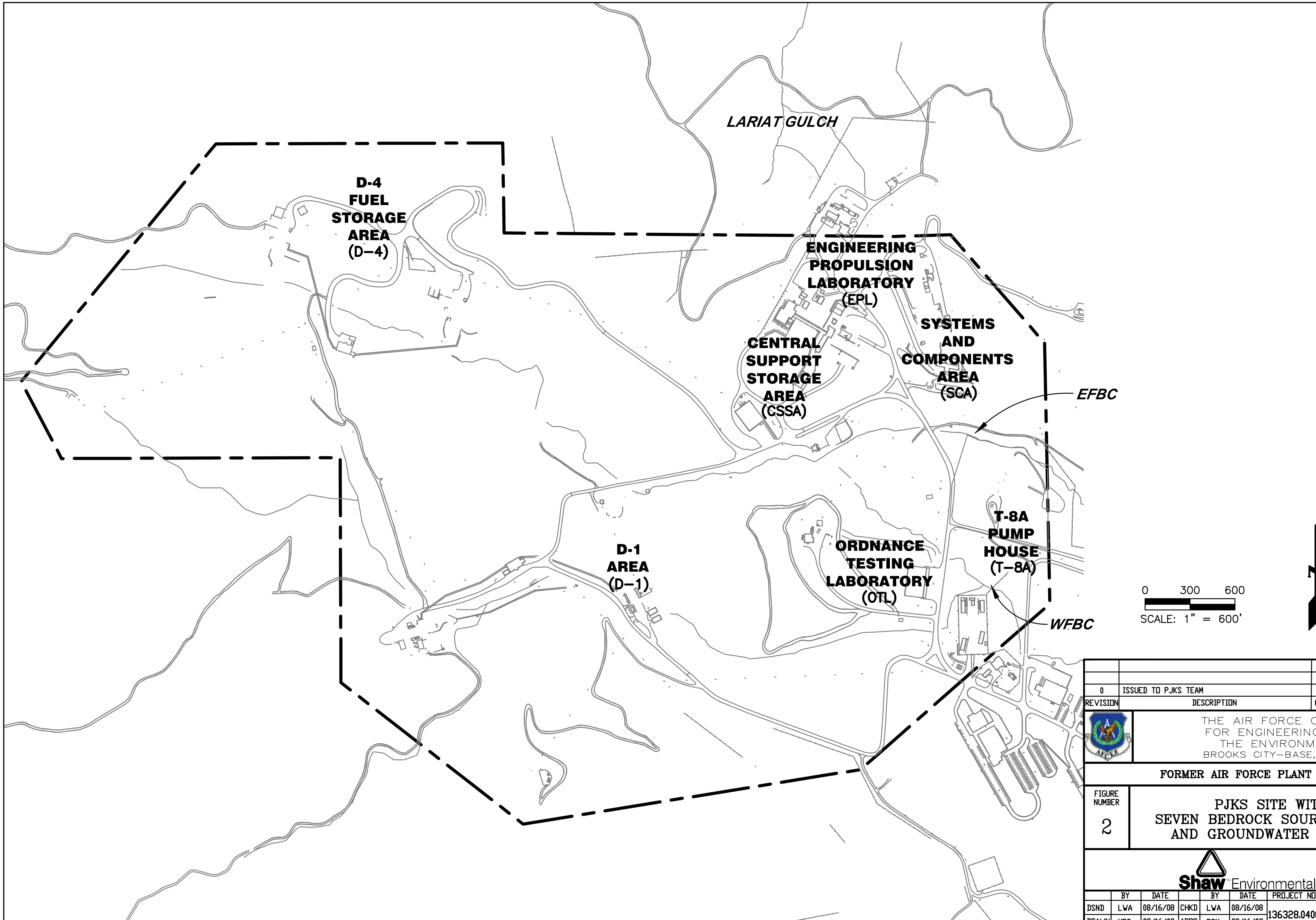
Shaw™ Environmental, Inc.

PROJECT NO.	REV.	FILE NAME
136328.0400	0	136328-01B

REVISION	DESCRIPTION	CHKD	APPR	DATE
0	ISSUE TO PJKS TEAM	LWA	PSM	06/15/10

	BY	DATE		BY	DATE		BY	DATE		BY	DATE
DSGN	LWA	08/29/06	DRAWN	MEC	08/29/06	CHKD	LWA	08/30/06	APPR	PSM	08/30/06

:\\GOLDEN\DENDFSROOT\ACAD_REF\PJKS\136328\136328-01B.DWG, ANSI A (8.5x11.0)



0	ISSUED TO PJKS TEAM	LWA	PSM	06/15/10
REVISION	DESCRIPTION	CHECKED	APPROVED	DATE

THE AIR FORCE CENTER
FOR ENGINEERING AND
THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

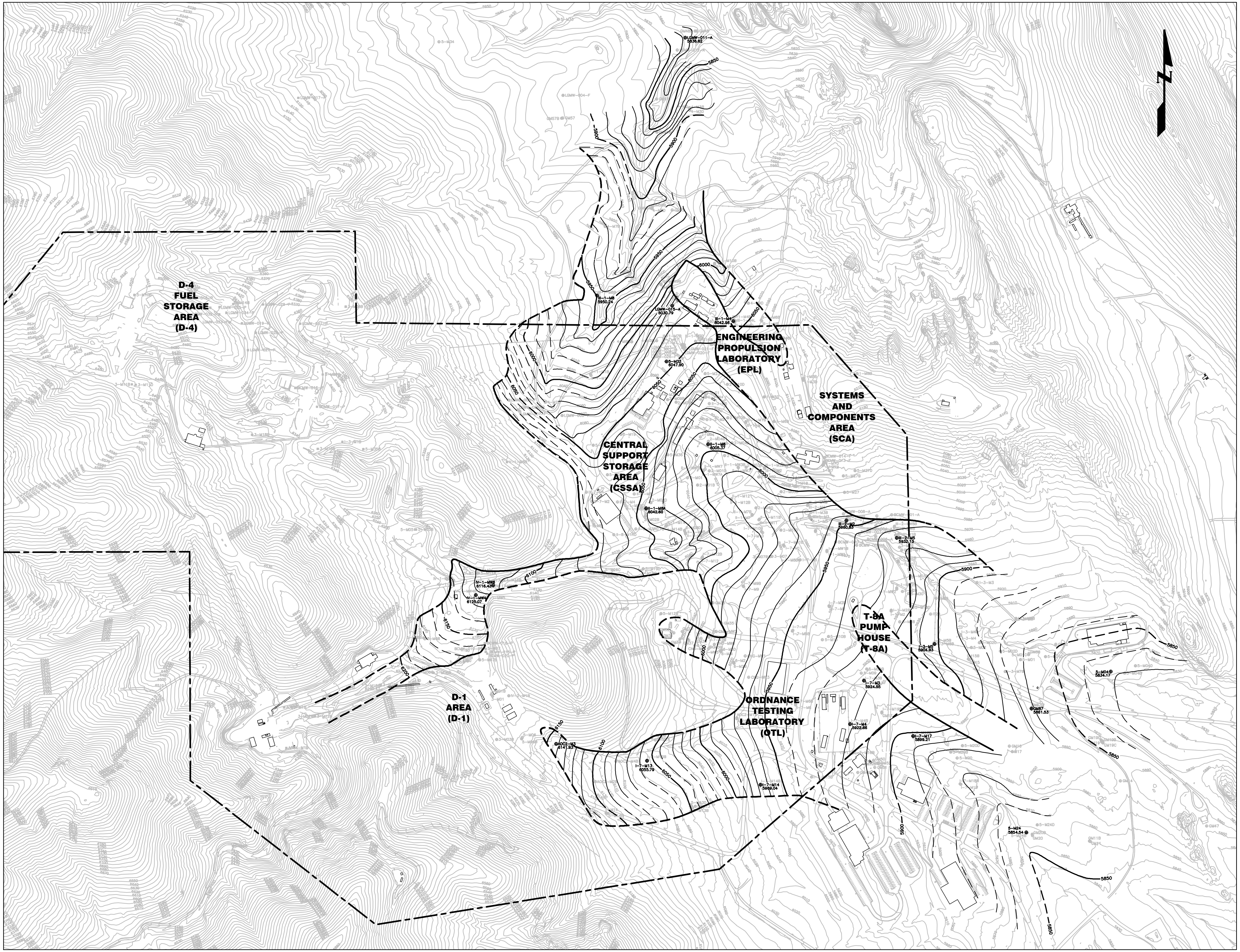
FIGURE NUMBER 2

PJKS SITE WITH
SEVEN BEDROCK SOURCE AREAS
AND GROUNDWATER PLUMES

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DSND	LWA	08/16/08	CHKD	LWA	08/16/08	136328.0400	0	136328-02B
DRAWN	MEC	08/16/08	APPR	PSM	08/16/08			

I:\GOLDEN\DENDFSROOT\ACAD_REF\PJKS\136328\136328-02B.DWG



LEGEND

2-M10D	WELLS NOT MEASURED
5-M32	WELLS MEASURED IN FALL 2009
6077.96	GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL
	PJKS BOUNDARY
	EXTENT OF SATURATED ALLUVIUM (DASHED WHERE INFERRED)
6100	POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
	CONTOUR INTERVAL = 10 FT.

0 300 600 1200

SCALE: 1" = 600'

REVISION	DESCRIPTION		CHECKED	APPROVED	DATE
0	ISSUED TO AGENCY		JF	TC	06/15/10

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

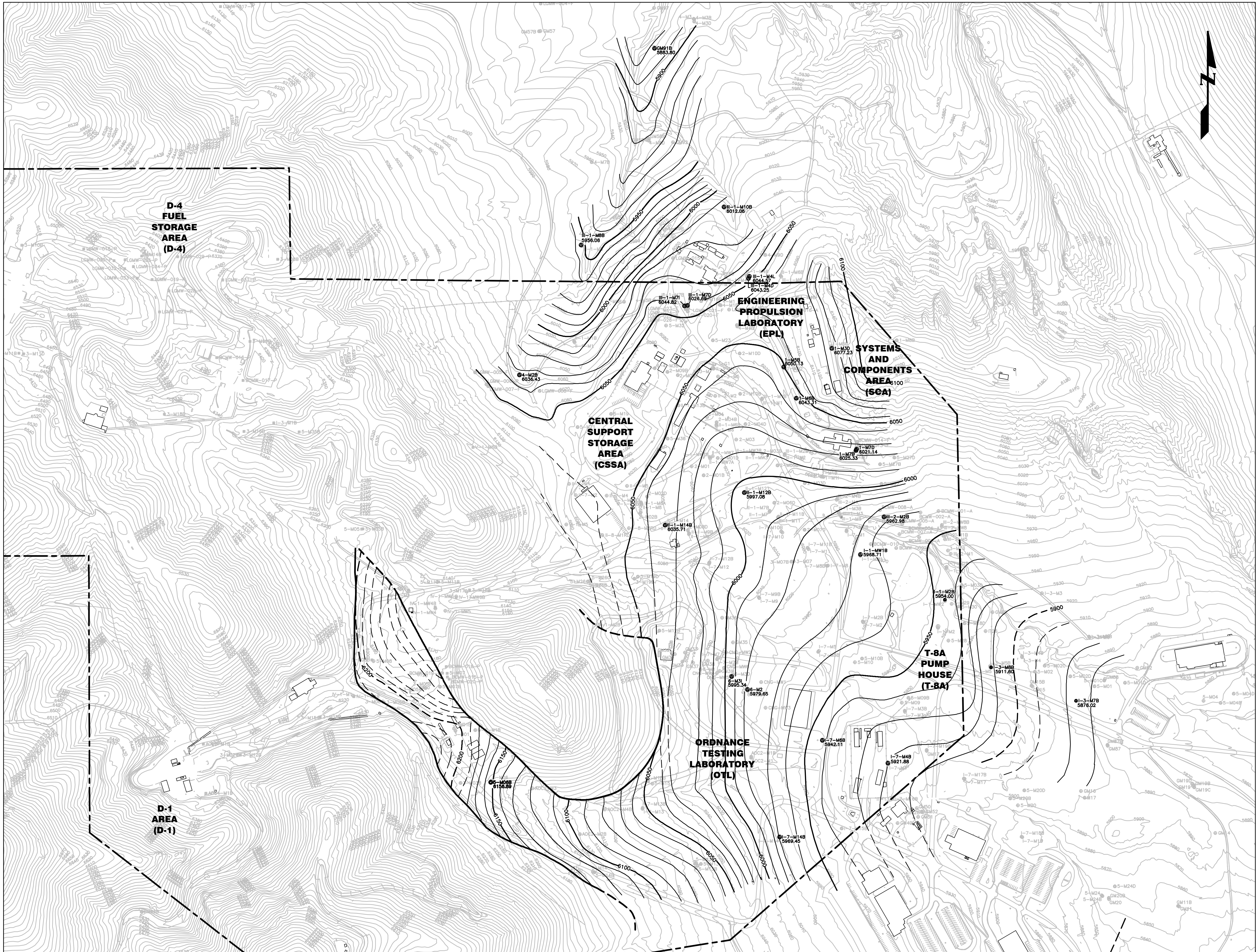
FIGURE NUMBER 3

ALLUVIAL AQUIFER POTENTIOMETRIC SURFACE MAP FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-03B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

D:\136328\136328-03B.dwg



LEGEND

2-M10D	WELLS NOT MEASURED
5-M32	WELLS MEASURED IN FALL 2009
6077.96	GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL
	PJKS BOUNDARY
	PRECAMBRIAN/FOUNTAIN FORMATION CONTACT (DASHED WHERE INFERRED)
6100	POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
	CONTOUR INTERVAL = 10 FT.

0 250 500 1000

SCALE: 1" = 500'

REVISION	DESCRIPTION		CHECKED	APPROVED	DATE
0	ISSUED TO AGENCY	JF	TC		06/15/10

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 4

FOUNTAIN AQUIFER POTENTIOMETRIC SURFACE MAP FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-04B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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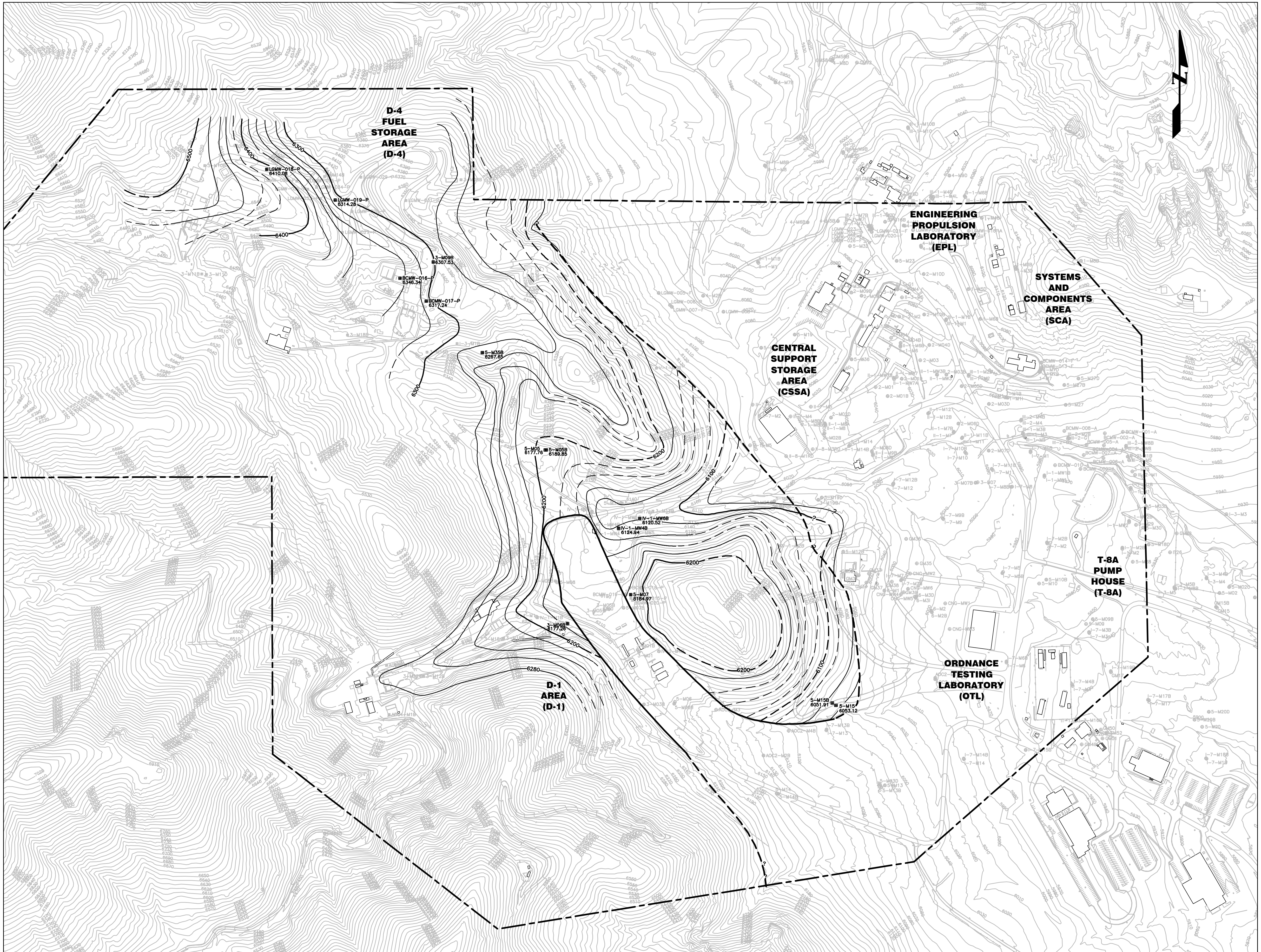

LEGEND

2-M10D	WELLS NOT MEASURED
5-M32	WELLS MEASURED IN FALL 2009
6077.96	GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL
	PJKS BOUNDARY
	PRECAMBRIAN/FOUNTAIN FORMATION CONTACT (DASHED WHERE INFERRED)
6100	POTENTIOMETRIC SURFACE CONTOUR (DASHED WHERE INFERRED)
	CONTOUR INTERVAL = 20 FT.

0 250 500 1000

SCALE: 1" = 500'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCY	JF	TC	06/15/10

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 5

PRECAMBRIAN AQUIFER POTENTIOMETRIC SURFACE MAP FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-05B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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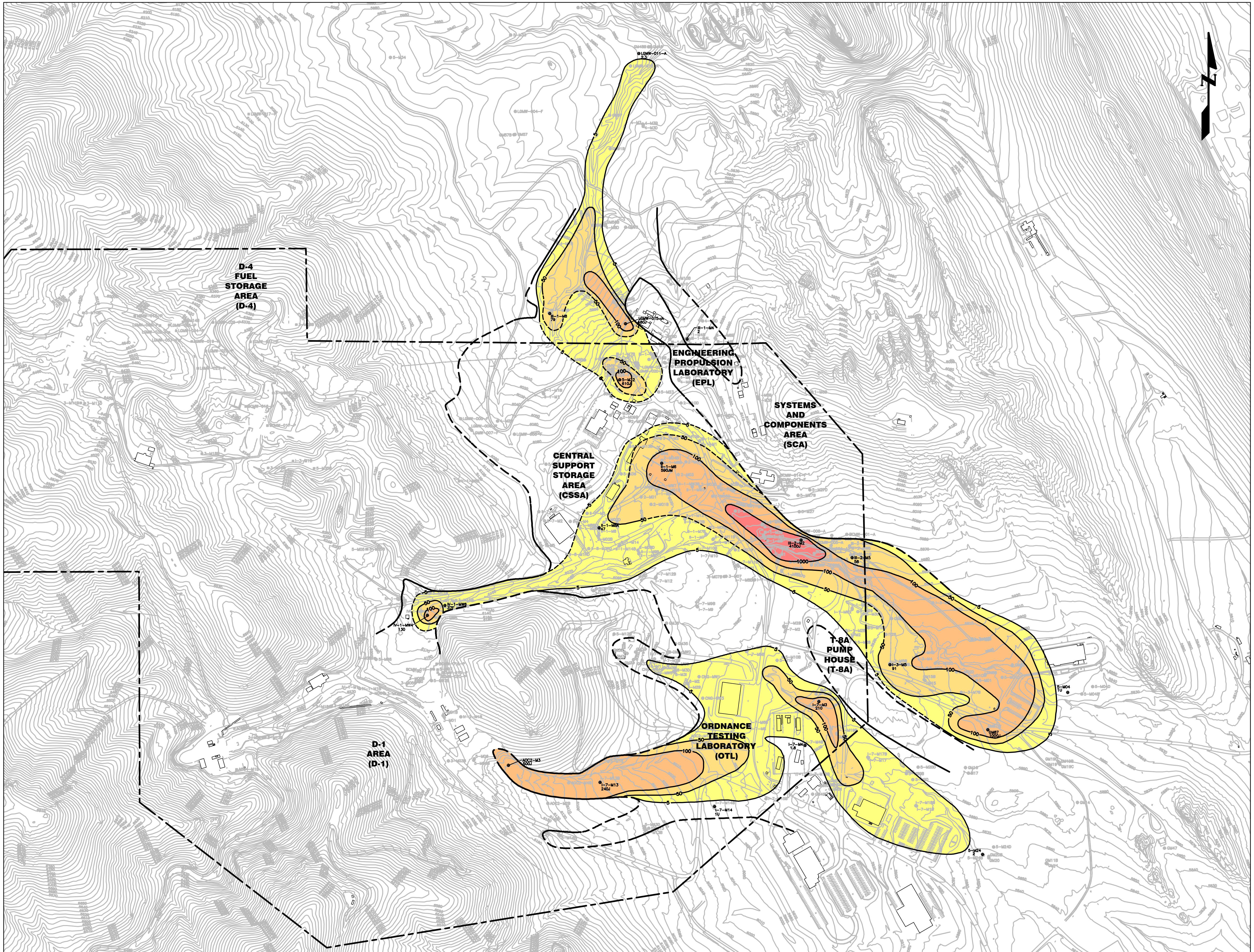

NOTE

1. PLUMES BASED ON CURRENT AND HISTORICAL DATA

LEGEND

- 2-M100 WELLS NOT SAMPLED
- 5-M32 WELLS SAMPLED IN FALL 2009
- 720J TCE CONCENTRATION IN μg/L
- PJKS BOUNDARY
- EXTENT OF SATURATED ALLUVIUM (DASHED WHERE INFERRED)
- 5 CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
- 5–50 μg/L
- 50–100 μg/L
- 100–1,000 μg/L
- >1,000 μg/L

DATA QUALIFIERS

F AN ESTIMATED VALUE – THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

J AN ESTIMATED VALUE – AS WITH "F" QUALIFIER, THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

JM ESTIMATED VALUE BECAUSE MATRIX SPIKE RECOVERY OUTSIDE QUALITY CONTROL LIMITS.

#U RESULT IS NON-DETECT WITH #=REPORTING LIMIT. DIFFERENCES IN THE REPORTING LIMIT VALUE ARE DUE TO THE DILUTION FACTOR.

0 300 600 1200

SCALE: 1" = 600'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCY	JF	TC	06/15/10

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 6

TCE PLUME ALLUVIAL AQUIFER FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-06B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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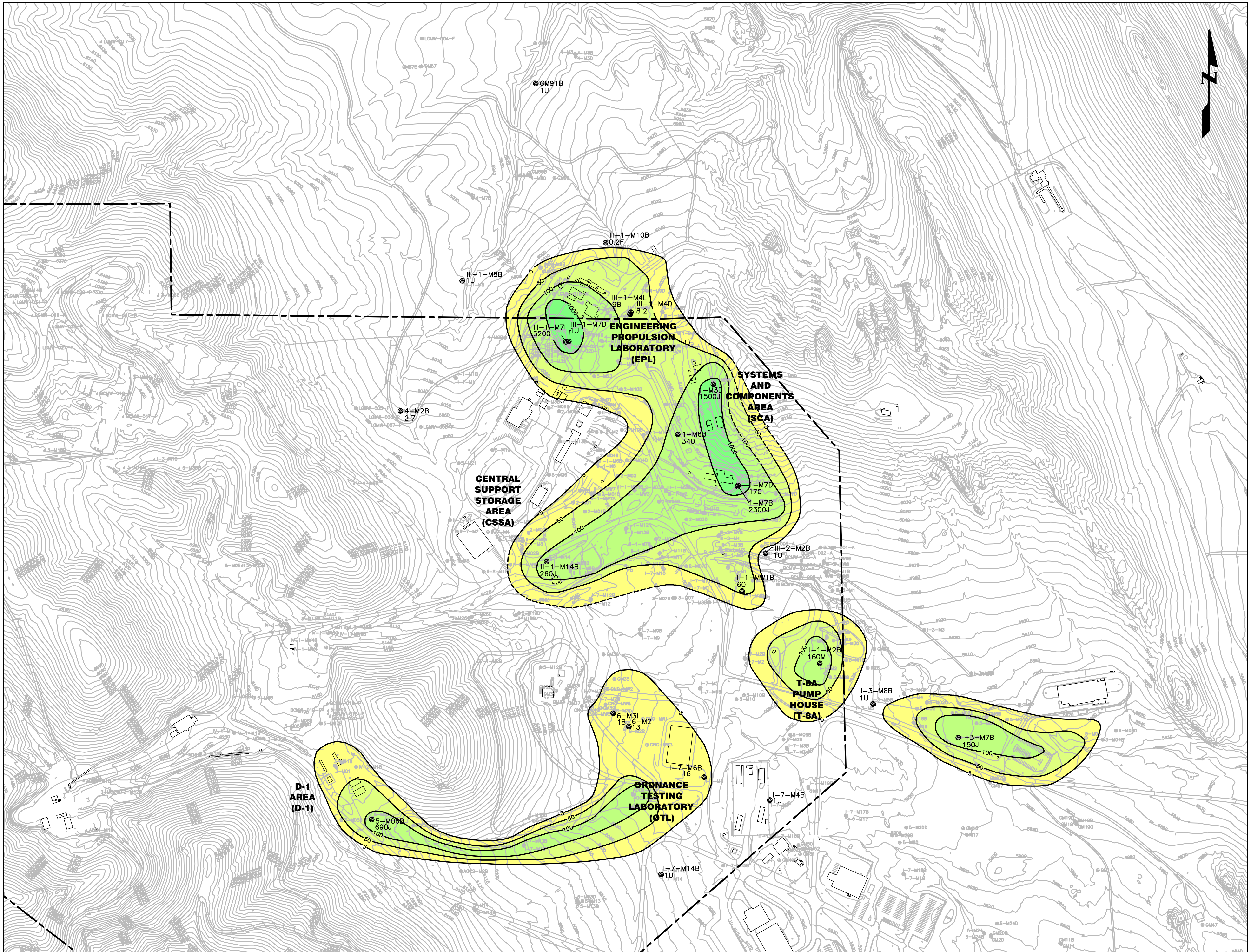

NOTE

1. PLUMES BASED ON CURRENT AND HISTORICAL DATA

LEGEND

2-M10D	WELLS NOT SAMPLED
III-1-M4L	WELLS SAMPLED IN FALL 2009
91	TCE CONCENTRATION IN μg/L
	PJKS BOUNDARY
5	CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
	5-50 μg/L
	50-100 μg/L
	100-1,000 μg/L
	>1,000 μg/L

DATA QUALIFIERS

F AN ESTIMATED VALUE – THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

J AN ESTIMATED VALUE – AS WITH "F" QUALIFIER, THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

JM ESTIMATED VALUE BECAUSE MATRIX SPIKE RECOVERY OUTSIDE QUALITY CONTROL LIMITS.

#U RESULT IS NON-DETECT WITH #=REPORTING LIMIT. DIFFERENCES IN THE REPORTING LIMIT VALUE ARE DUE TO THE DILUTION FACTOR.

0 250 500 1000

SCALE: 1" = 500'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	JF	TC	06/15/10

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BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 7

TCE PLUME FOUNTAIN AQUIFER FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-07B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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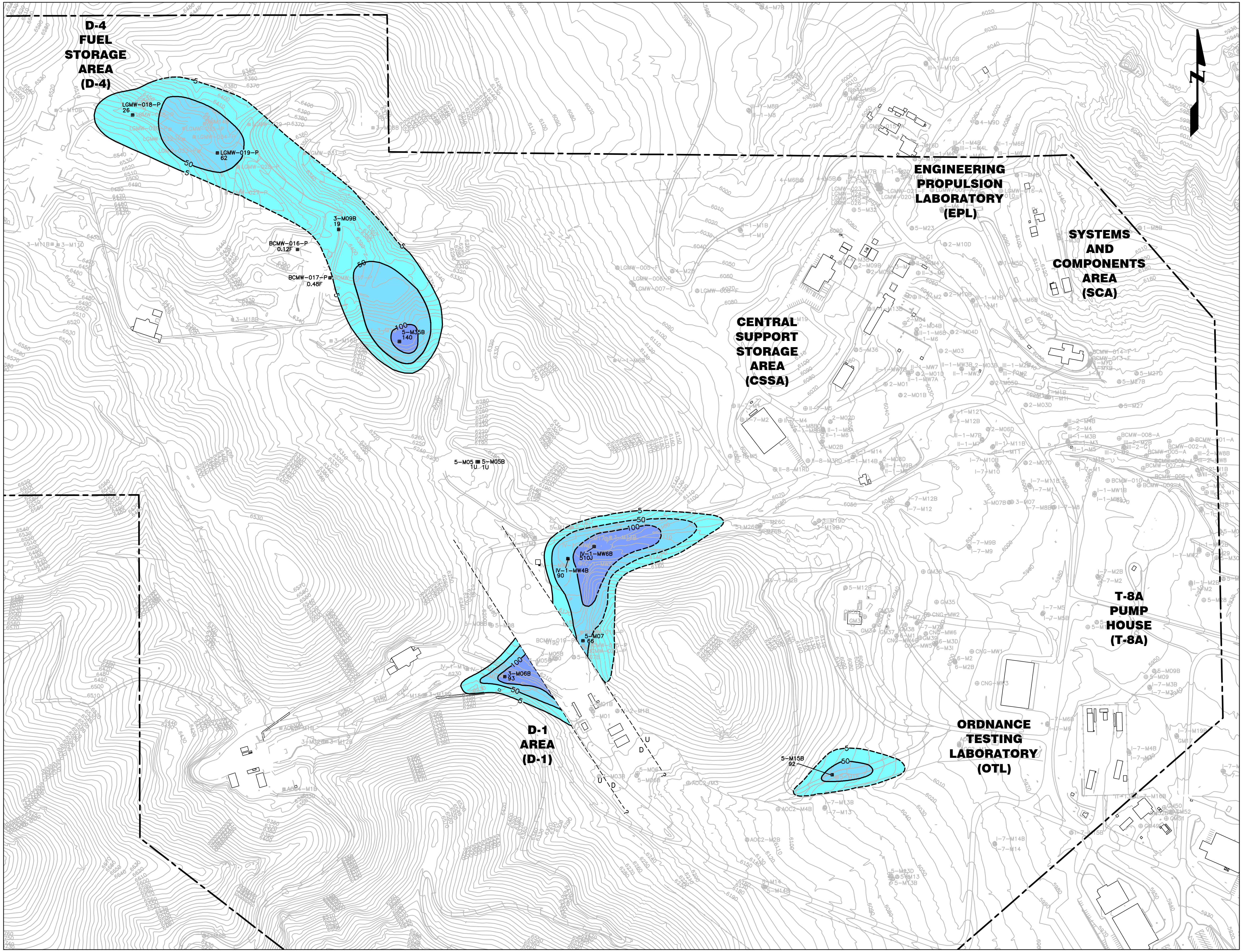

NOTE

1. PLUMES BASED ON CURRENT AND HISTORICAL DATA

LEGEND

- 2-M10D — WELLS NOT SAMPLED
- 5-M32 — WELLS SAMPLED IN FALL 2009
- 720J — TCE CONCENTRATION IN $\mu g/L$
- PJKS BOUNDARY
- 5 — CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
- U D — FAULTS
- 5-50 $\mu g/L$
- 50-100 $\mu g/L$
- 100-1,000 $\mu g/L$

DATA QUALIFIERS

F AN ESTIMATED VALUE – THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

J AN ESTIMATED VALUE – AS WITH "F" QUALIFIER, THE ANALYTE WAS POSITIVELY IDENTIFIED BUT THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.

#U RESULT IS NON-DETECT WITH #=REPORTING LIMIT. DIFFERENCES IN THE REPORTING LIMIT VALUE ARE DUE TO THE DILUTION FACTOR.

0 200 400 800

SCALE: 1" = 400'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	JF	TC	06/15/10

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BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 8

TCE PLUME PRECAMBRIAN AQUIFER FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-08B
DRAWN	JVR	12/31/09	APPROVED	TC	03/12/10			

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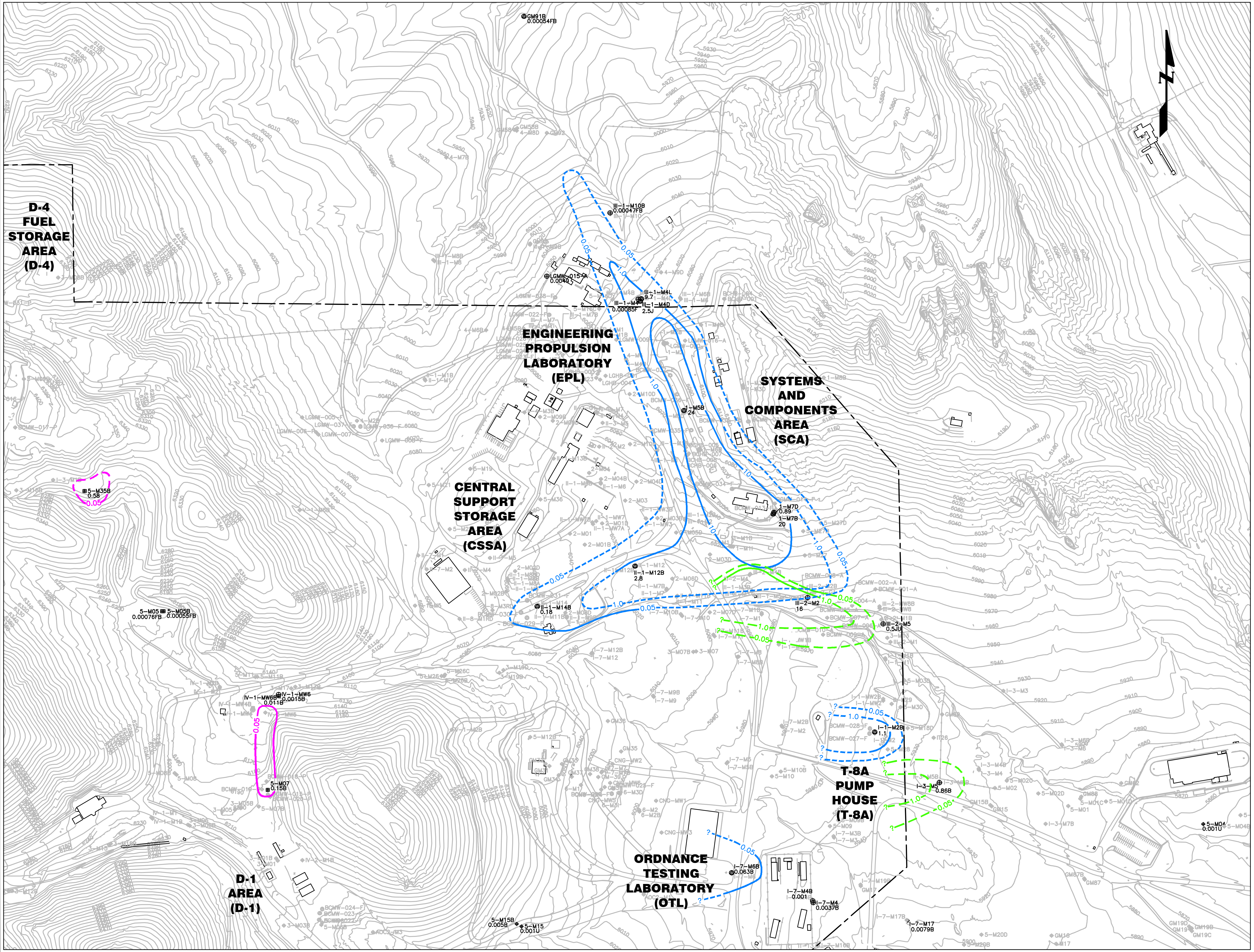

LEGEND

- 5-M11B — WELLS NOT SAMPLED
- 5-M35B — WELLS SAMPLED IN SPRING 2009
- 0.001U — NDMA CONCENTRATION IN μg/L
- ND — NOT DETECTED (LABORATORY DETECTION LIMIT = 0.5 μg/L)
- PJKS BOUNDARY
- 0.05 ? — ALLUVIAL CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
- 0.05 ? — FOUNTAIN CONCENTRATION CONTOUR (DASHED WHERE INFERRED)
- 0.05 ? — PRECAMBRAIN CONCENTRATION CONTOUR (DASHED WHERE INFERRED)

DATA QUALIFIERS

- B — THE ANALYTE WAS FOUND IN AN ASSOCIATED BLANK.
- F — THE ANALYTE WAS POSITIVELY IDENTIFIED, HOWEVER THE ASSOCIATED NUMERICAL VALUE IS BELOW THE REPORTING LIMIT.
- J — THE ANALYTE WAS POSITIVELY IDENTIFIED, THE QUANTITATION IS AN ESTIMATE.
- U — THE ANALYTE WAS ANALYZED FOR, BUT NOT DETECTED. NUMERICAL VALUE PRECEDING THE "U" IS THE REPORTING LIMIT.

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCY	JF	TC	06/15/10

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FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 9

NDMA PLUME COMBINED AQUIFERS FALL 2009

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-09B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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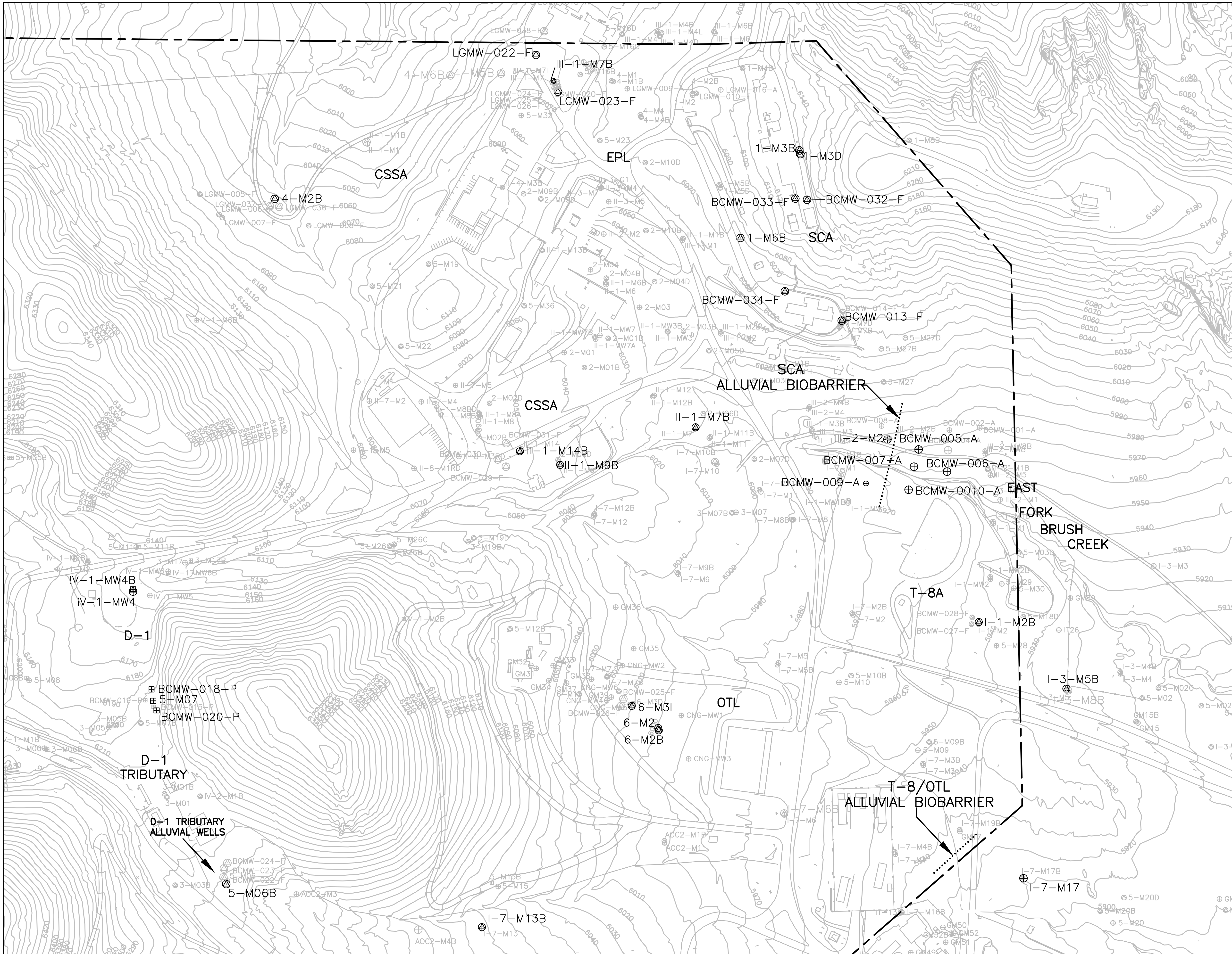

LEGEND

BCMW-031-F	PERFORMANCE MONITORING WELLS
IV-1-MW6	ALLUVIUM WELL
BCMW-011-F	FOUNTAIN WELL
3-M04B	PRECAMBRIAN WELL

0 150 300 600

SCALE: 1" = 300'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	JF	TC	06/15/10

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BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 10

D-1, EPL, SCA, CSSA, OTL, T-8A AND D-1 TRIBUTARY PERFORMANCE MONITORING WELL LOCATIONS

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	JF	12/31/09	CHECKED	JF	03/12/10	136328.0400	0	136328-010B
DRAWN	JWR	12/31/09	APPROVED	TC	03/12/10			

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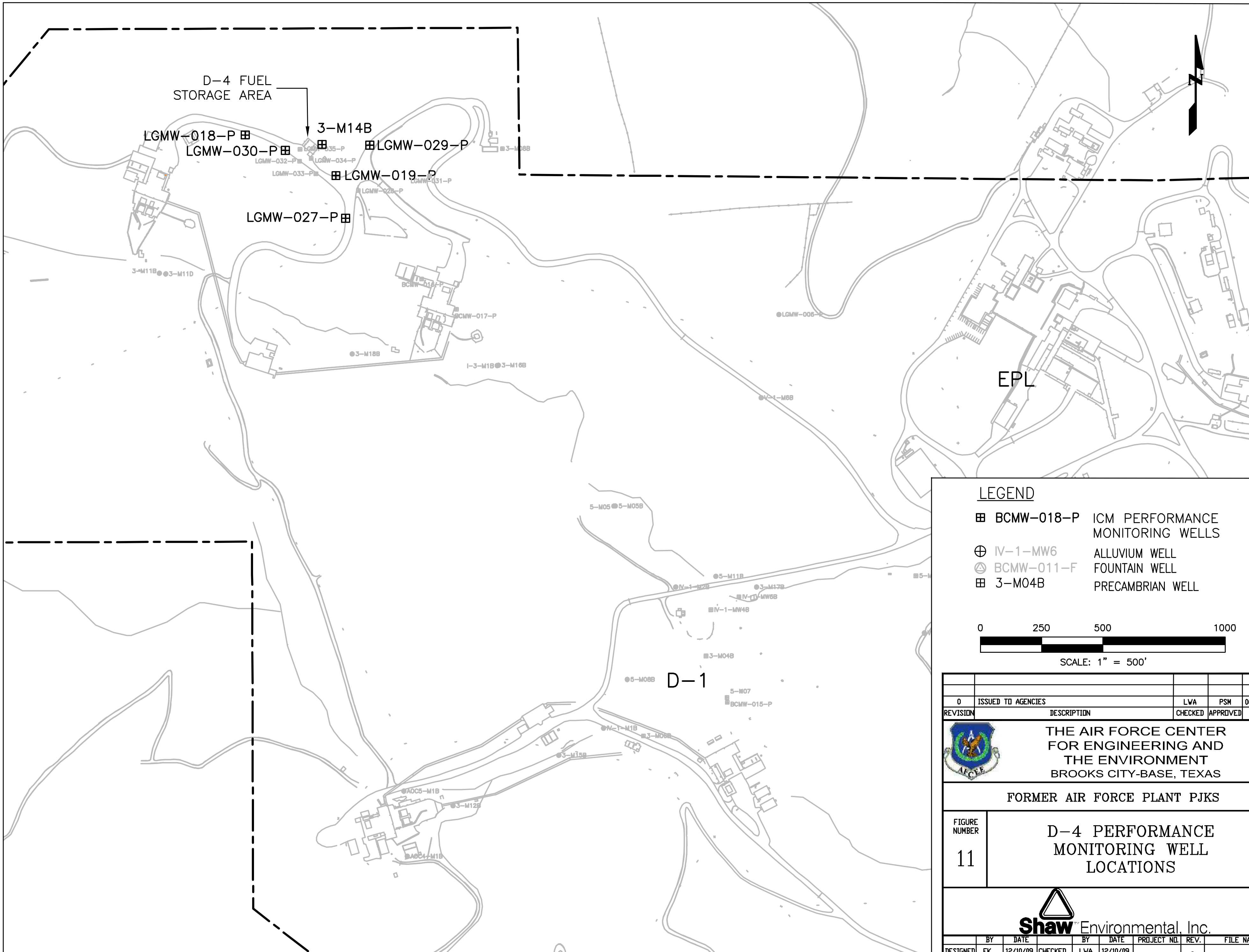

LEGEND

⊞	BCMW-018-P	ICM PERFORMANCE MONITORING WELLS
⊕	IV-1-MW6	ALLUVIUM WELL
△	BCMW-011-F	FOUNTAIN WELL
⊞	3-M04B	PRECAMBRIAN WELL

0 250 500 1000

SCALE: 1" = 500'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	LWA	PSM	06/15/10

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BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 11

D-4 PERFORMANCE
MONITORING WELL
LOCATIONS

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	EK	12/10/09	CHECKED	LWA	12/10/09	136328.0400	0	136328-011B
DRAWN	JWR	12/10/09	APPROVED	PSM	12/10/09			

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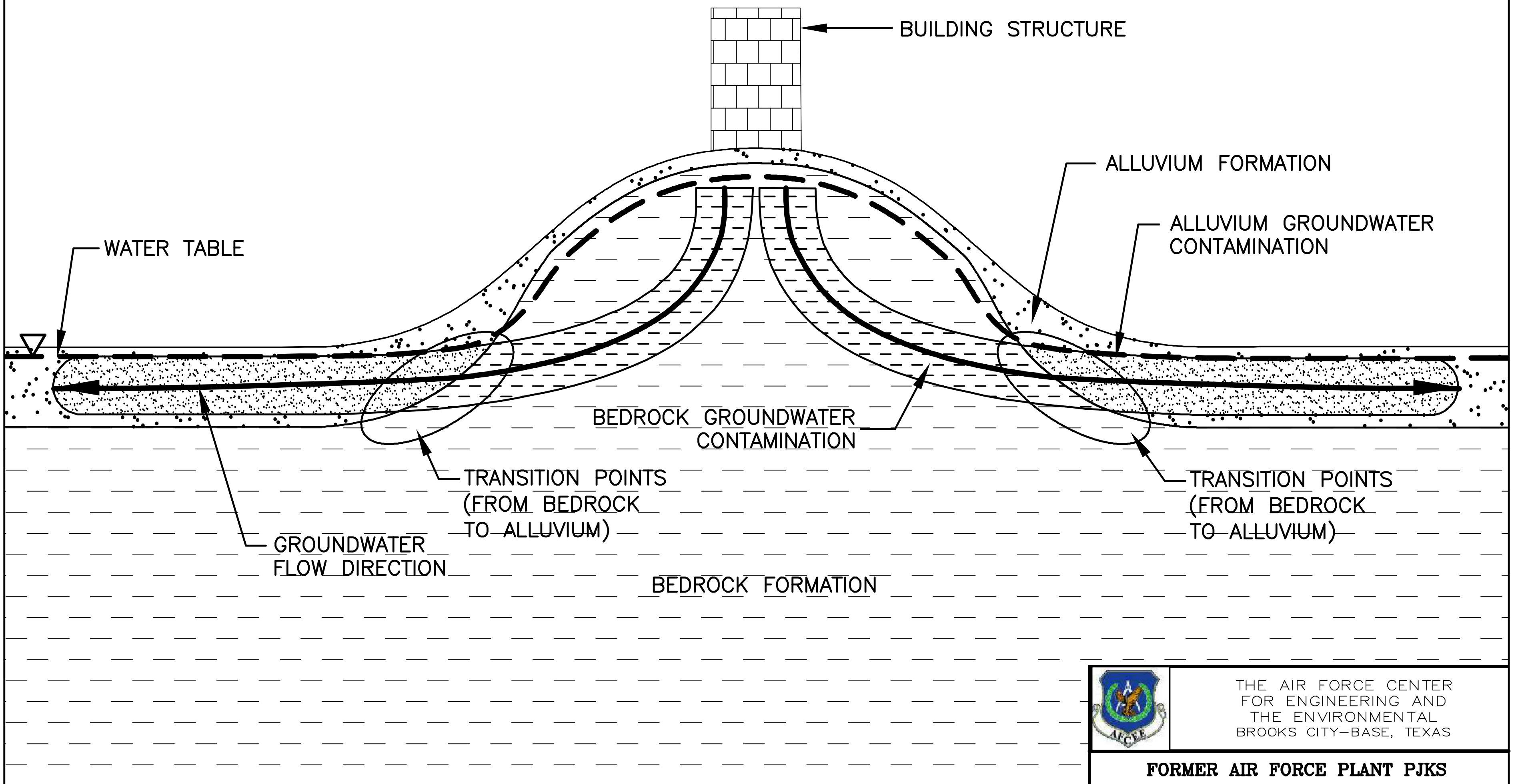


THE AIR FORCE CENTER
FOR ENGINEERING AND
THE ENVIRONMENTAL
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 12

CONCEPTUAL SITE MODEL

Shaw Environmental, Inc.

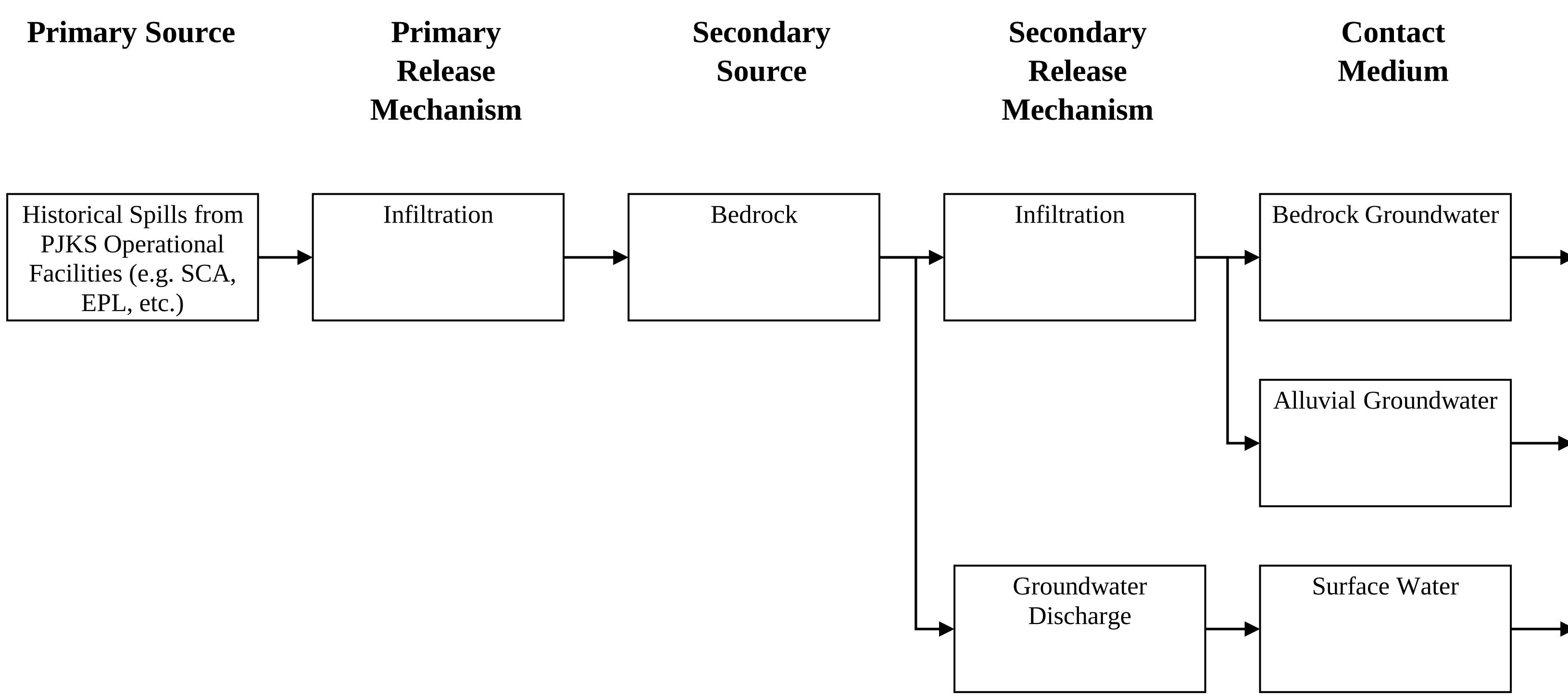
0	ISSUED TO AGENCIES	TC	PSM	06/15/10
REVISION	DESCRIPTION	CHKD	APPR	DATE

	BY	DATE		BY	DATE		BY	DATE		BY	DATE
DSGN	TC	12/31/09	DRAWN	JWR	12/31/09	CHKD	TC	03/12/10	APPR	TC	03/12/10

PROJECT NO.	REV.	FILE NAME
136328.0400	0	136328-012B

:\\GOLDEN\DENDFSROOT\ACAD_REF\PJKS\136328\136328-12B.DWG

Figure 13
Generalized Conceptual Site Model
Former Air Force Plant PJKS Groundwater

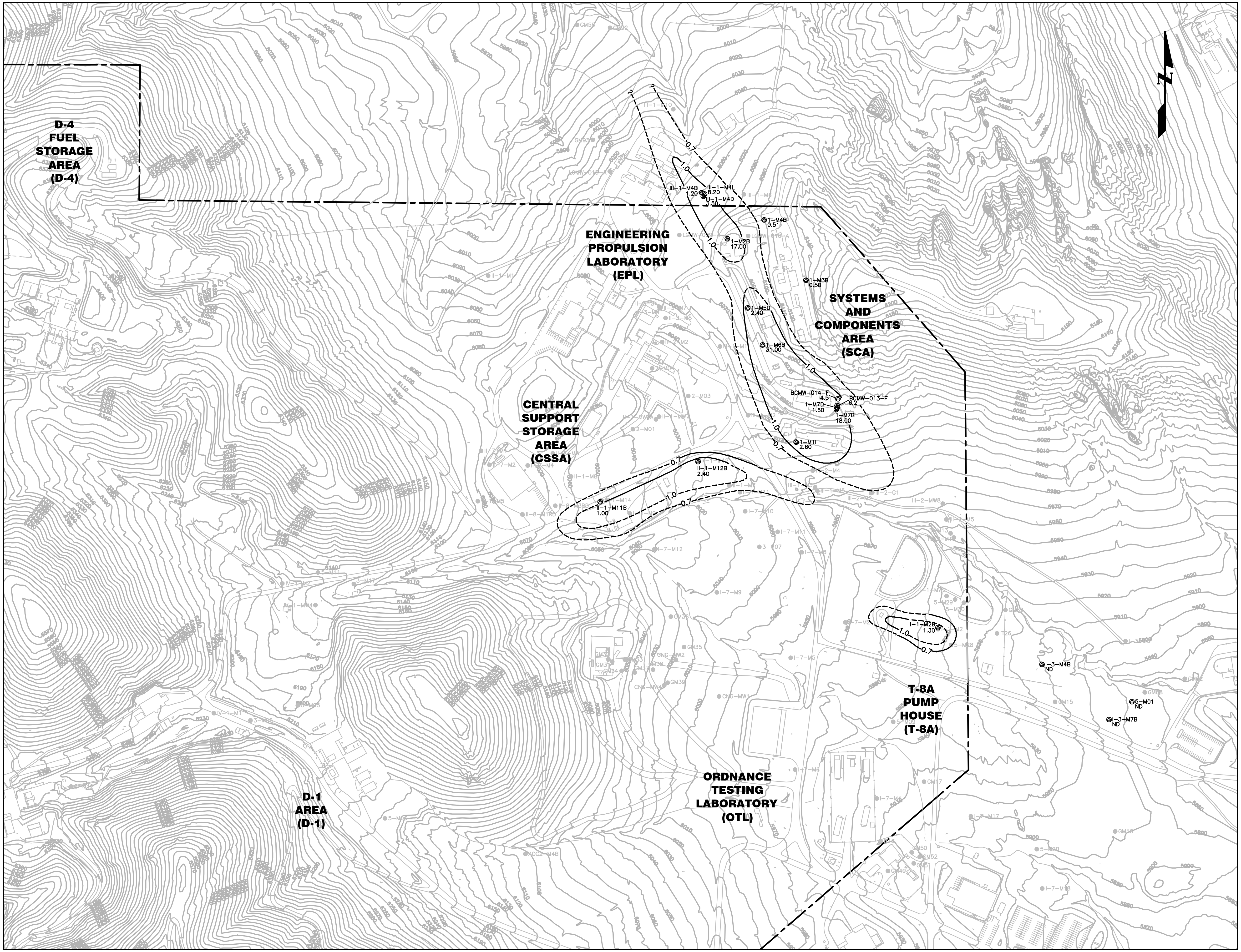


POTENTIAL RECEPTORS

	HUMAN			ECOLOGICAL	
Exposure Route	Current Site Worker	Future Site Worker	Future Offsite Receptor	Terrestrial	Aquatic
Ingestion		✓(1)	✓		
Inhalation (vapor)(2)		✓	✓		
Dermal Contact		✓	✓		
Ingestion		✓	✓		
Inhalation (vapor)(2)		✓	✓		
Dermal Contact		✓	✓		
Ingestion		✓	✓		
Inhalation (vapor)					
Dermal Contact		✓	✓		

1) Not likely a completed pathway. This designation is conditional on changed land use or future use of groundwater.

2) Based on EPA's Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway From Groundwater and Soils (EVI) (OSWER, November 29, 2002) definition of "inhabited buildings", which are structures with enclosed air space that are designed for human occupancy and are "near" (100 feet laterally or vertically) known groundwater contaminants listed in Table 1 of the EVI. Trichloroethene, cis-1,2-Dichloroethene, trans-1,2-Dichloroethene, 1,1-Dichloroethene, and vinyl chloride are listed on Table 1 of the EVI.



LEGEND

2-M10D WELLS NOT SAMPLED

1-M7B WELLS SAMPLED IN FALL 2004

18.00 NDMA CONCENTRATION IN μg/L

ND NOT DETECTED (LABORATORY DETECTION LIMIT = 0.5 μg/L

PJKS BOUNDARY

1.0 — ? CONCENTRATION CONTOUR (DASHED WHERE INFERRED)

0 200 400 800

SCALE: 1" = 400'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	TC	PSM	06/15/10

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BROOKS CITY-BASE, TEXAS

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FIGURE NUMBER 15

NDMA PLUME
FOUNTAIN AQUIFER
FALL 2004

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	TR	03/09/05	CHECKED	TC	03/17/05	136328.0400	0	136328-015B
DRAWN	MEC	03/09/05	APPROVED	PSM	03/17/05			

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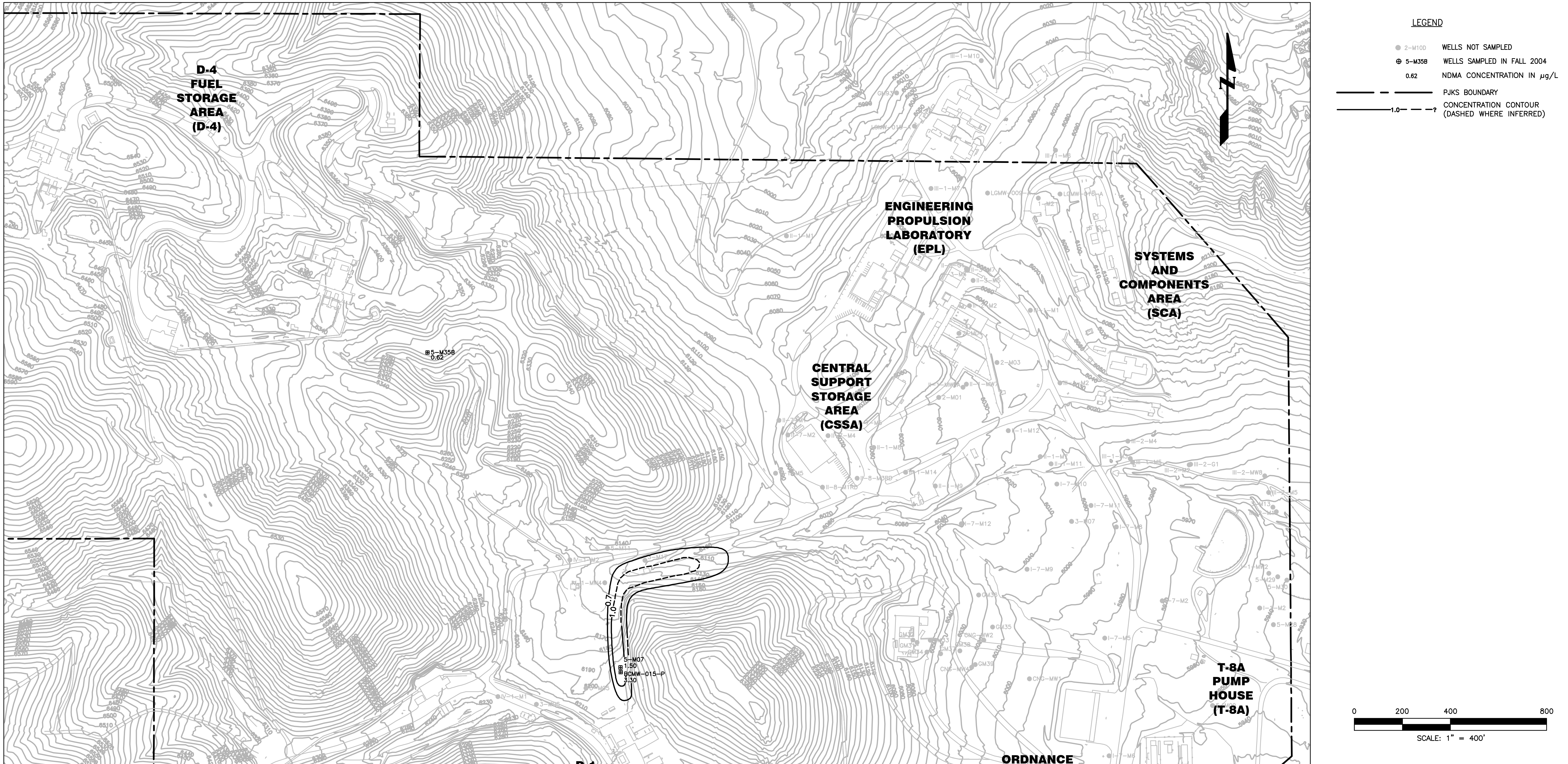

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	TC	PSM	06/15/10

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BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 16

NDMA PLUME
PRECAMBRIAN
AQUIFER FALL 2004

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	TR	03/09/05	CHECKED	TC	03/17/05	136328.0400	0	136328-016B
DRAWN	MEC	03/09/05	APPROVED	PSM	03/17/05			

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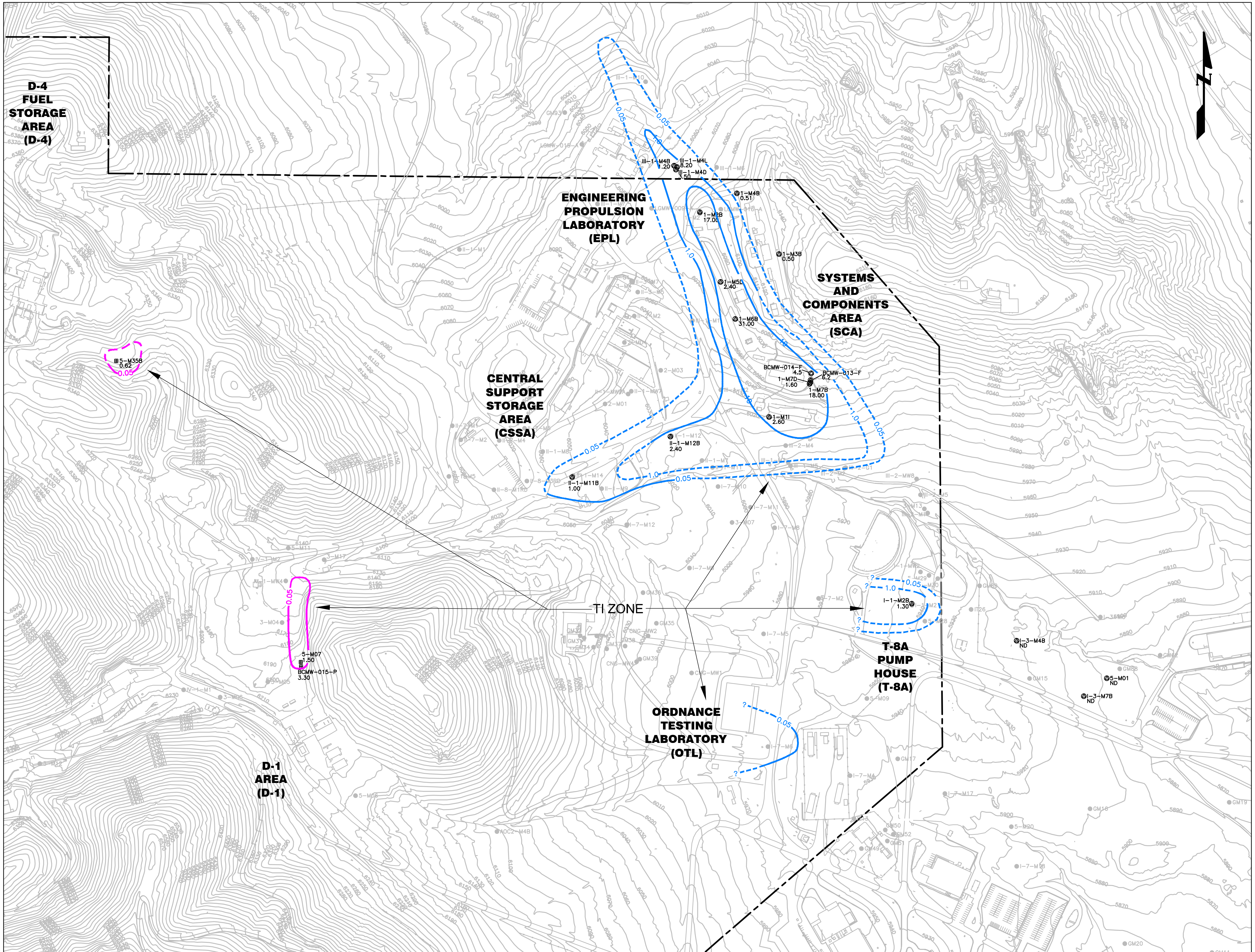

LEGEND

2-M100 WELLS NOT SAMPLED

18.00 NDMA CONCENTRATION IN $\mu g/L$

ND NOT DETECTED (LABORATORY DETECTION LIMIT = 0.5 $\mu g/L$)

PJKS BOUNDARY

0.05 ? FOUNTAIN CONCENTRATION CONTOUR (DASHED WHERE INFERRED)

0.05 ? PRECAMBRAIN CONCENTRATION CONTOUR (DASHED WHERE INFERRED)

NOTE:

TI ZONE IS DEFINED BY THE BEDROCK GROUNDWATER PLUMES FOOTPRINTS FOR NDMA (INCLUDES FOUNTAIN FORMATION AND PRECAMBRIAN AQUIFER).

0 200 400 800

SCALE: 1" = 400'

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	TC	PSM	06/15/10

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 17

TI ZONE

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DESIGNED	TR	03/09/05	CHECKED	TC	03/17/05	136328.0400	0	136328-017B
DRAWN	MEC	03/09/05	APPROVED	PSM	03/17/05			

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APPENDIX A

SOIL CLOSURE LETTERS

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION
http://www.cdphe.state.co.us/hm/

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-3300
Fax (303) 759-5355

222 S. 6th Street, Room 232
Grand Junction, Colorado 81501-2768
Phone (970) 248-7164
Fax (970) 248-7198

Colorado Department
of Public Health
and Environment

CERTIFIED MAIL No. 0283 1841
Return Receipt Requested
August 23, 2000

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

Re: Closure Certification for the Open Detonation/Open Burning Unit Located at Air Force Plant PJKS CO 7570090038

Dear Mr.Kunas:

We have reviewed the Closure Report, Open Detonation/Open Burning Unit, U.S. Air Force Plant PJKS. We have reached a final decision that the closure complies with the Closure Performance Standard in 6 CCR 1007-3, §264.111, the process approved in the Resource Conservation and Recovery Act Open Detonation/Open Burning Unit Closure Plan, and to accept the closure certification for clean closure of the Open Detonation/Open Burning Unit. In accordance with 6 CCR 1007-3, § 266.14(l), our records will be changed to show that the Open Detonation/Open Burning Unit has been clean closed. Please call Charles Johnson at (303) 692-3348 if you have any questions regarding this correspondence.

Sincerely,

Walter Avramenko, Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: George Larsen, LMSSC
Mira Neumiller, CDPHE
David Walker, CDPHE
Corbin Darling, EPA
William Allison, AGO
Bill Bath, LMSSC
David Rathke, EPA
Felix Flechas, EPA
Jefferson County Health Department

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION
http://www.cdphe.state.co.us/hm/

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-3300
Fax (303) 759-5355

222 S. 6th Street, Room 232
Grand Junction, Colorado 81501-2768
Phone (970) 248-7164
Fax (970) 248-7198

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 0283 1773
Return Receipt Requested
August 7, 2000

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

Re: Closure Certification for the Waste Propellant Storage Unit Located at Air Force Plant PJKS
CO 7570090038

Dear Mr.Kunas:

We have reviewed the Closure Report, Waste Propellant Storage Unit, U.S. Air Force Plant PJKS. We have reached a final decision that the closure complies with the Closure Performance Standard in 6 CCR 1007-3, §264.111, the process approved in the Resource Conservation and Recovery Act Waste Propellant Storage Unit Closure Plan, and to accept the closure certification for the Waste Propellant Storage Unit. In accordance with 6 CCR 1007-3, § 266.14(l), our records will be changed to show that the Waste Propellant Storage Unit has been clean closed. Please call Charles Johnson at (303) 692-3348 if you have any questions regarding this correspondence.

Sincerely,

Walter Avramenko, Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: George Larsen, LMSSC
Mira Neumiller, CDPHE
David Walker, CDPHE
Corbin Darling, EPA
William Allison, AGO
Bill Bath, LMSSC
David Rathke, EPA
Felix Flechas, EPA
Jefferson County Health Department

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 2456 1817
Return Receipt Requested

June 8, 2001

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Closure Certification for the Decontamination Trailer Tank Area and Spill Area Unit Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment (the Department) has incorporated your June 5, 2001 Revisions into your April 16, 2001 Closure Report for the Decontamination Trailer Tank Area and Spill Area Unit (Closure Report). Based on our review of the Closure Report we have reached a final decision that the closure complies with the Closure Performance Standard in 6 CCR 1007-3, 264.111, the process approved in the Resource Conservation and Recovery Act Modified Closure Plan for the Decontamination Trailer Tank Area and Spill Area Unit, and to accept the closure certification for residential/unrestricted use clean closure of the Decontamination Trailer Tank Area and Spill Area Unit. In accordance with 6 CCR 1007-3, 266.14(1), our records will be changed to show that the Decontamination Trailer Tank Area and Spill Area Unit has been clean closed. Please call Dave Walker at (303) 692-3354 if you have any questions regarding this correspondence.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Charles G. Johnson, CDPHE
William Allison, AGO
David Rathke, EPA
Dave Walker CDPHE
Marsha Bates, Stone and Webster
William Bath, Lockheed Martin Space Systems
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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HAZARDOUS MATERIALS AND WASTE MANAGEMENT DIVISION
http://www.cdphe.state.co.us/hm/

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-3300
Fax (303) 759-5355

222 S. 6th Street, Room 232
Grand Junction, Colorado 81501-2768
Phone (970) 248-7164
Fax (970) 248-7198

Colorado Department of Public Health and Environment

September 7, 2001

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Closure Certification for the BC-79 Unit Located at Air Force Plant PJKS
CO 7570090038

Dear Mr.Kunas:

We reviewed the Closure Report, BC-79 Unit, U.S. Air Force Plant PJKS dated August 16, 2001. We have reached a final decision that the closure complies with the Closure Performance Standard in 6 CCR 1007-3, §264.111 and the process approved in the Resource Conservation and Recovery Act BC-79 Closure Plan. The closure certification was verified during a unit inspection conducted by the state health department and the U.S. Environmental Protection Agency on September 6, 2001. Therefore, we are accepting the closure certification for the BC-79 Unit. In accordance with 6 CCR 1007-3, § 266.14(l), our records will be changed to show that the BC-79 Unit has been clean closed. In addition, please find attached a copy of the inspection form completed during closure certification inspection. Please call me at (303) 692-3348 if you have any questions regarding this correspondence.

Sincerely,

Charles J. Johnson

Charles G. Johnson
Hazardous Waste Corrective Action Unit
Compliance Program

w/enclosure
cc: Bill Bath, LMSSC
William Allison, AGO
David Rathke, EPA
Marsha Bates, Stone and Webster Environmental Technology and Services
Jefferson County Health Department

STATE OF COLORADO

Bill Owens, Governor
Douglas H. Benevento, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

Laboratory Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 01271650
Return Receipt Requested

December 6, 2004

Mr. Corey T. Lam
Environmental Engineer
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Finalization of the Post-Closure Care Work Plan for the T-8A Surface Impoundment Unit located at the Former U.S. Air Force Plant PJKS, Project Number 992PJKS10C02-03. CO 7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) received one written Public Comments regarding your Post-Closure Care Work Plan for the T-8A Surface Impoundment Unit (Post-Closure Plan) during the October 14, 2004 through November 15, 2004 public comment period. The emailed comment and our response are attached. Based on our evaluation of the written comments, we have determined that no modifications to the Post-Closure Plan will be required. Therefore, the Post-Closure Care Work Plan for the T-8A Surface Impoundment Unit that was received on August 16, 2004 and issued for public comment on October 14, 2004 is approved and effective upon your receipt of this letter. Please call me at (303) 692-3354 if you have any technical questions regarding this correspondence and Mr. William Allison (303) 866-5361 of the Colorado Attorney General's Office for legal inquiries.

Sincerely,

David Walker

David Walker
Hazardous Waste Corrective Action Unit
Compliance Program

Enclosure
cc: Charles G. Johnson, CDPHE
William Allison, AGO
David Rathke, EPA
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department
Vicki Anderson, Lockheed Martin Space Systems Company

STATE OF COLORADO

Bill Ritter, Jr., Governor
Ned Calonge, M.D., Interim Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

Laboratory Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department
of Public Health
and Environment

December 17, 2009

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
ASC/EMR Building 8
1801 10th Street
Wright Patterson AFB
Dayton, OH 45433-7626

RE: No-Further Action Determination for Solid Waste Management Unit (SWMU) Nos. 9 and 14 and Contaminated Soil Area (CSA)-1, CSA-2, CSA-4, CSA-5, CSA-6 and the Discontinuous Area of Debris, D-1 Landfill Area, Former Air Force Plant PJKS: CO7570090038.

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has reviewed your Petition for a No Further Action Determination for Solid Waste Management Unit (SWMU) Nos. 9 and 14 and Contaminated Soil Area (CSA)-1, CSA-2, CSA-4, CSA-5, CSA-6 and the Discontinuous Area of Debris. The information provided in the Construction Completion Report (dated June 30, 2009), Appendix A of the Work Plan, D-1 Landfill Area Interim Measure, Revision 1 (dated November 16, 2004) and the Interim Corrective Measure Construction Completion Technical Memorandum for CSA-1, CSA-2 and CSA-6 At D-1 Area (dated August 28, 2006) demonstrates that the concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 9 and 14, CSA-1, CSA-2, CSA-4, CSA-5, CSA-6 and the Discontinuous Area of Debris do not pose an unacceptable risk to human health or the environment since they are below the Division's residential/unrestricted use and protective of groundwater soil remediation objectives. Therefore, the Division has determined that No Further Action is required for these SWMUs under Compliance Order On Consent No. 98-10-08-01. The U.S. EPA concurs with this decision.

Please call me at (303) 692-3354 with questions regarding this correspondence.

Sincerely,

David Walker

David Walker
Hazardous Waste Corrective Action Unit
Solid and Hazardous Waste Program

cc: Jason King, AGO
David Rathke, EPA Region 8
Larry Kimmel; EPA Region 8
Vicki Anderson, Lockheed Martin Space Systems Company
Thomas Cooper, Shaw Environmental & Infrastructure Group
Roy Laws, Jefferson County Health Department

DO 26
R2.15

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 9649 7141
Return Receipt Requested

January 13, 2003

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Decision on Petition for No Further Action For Solid Waste Management Unit Nos. 10 and 11 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your Petition for No Further Action for Solid Waste Management Unit (SWMU) No. 10, Upper (LOX) Volcano, and No. 11, Lower (Fuel) Volcano. Based on the information provided in the Draft Addendum to the Construction Completion Report Early Action – Phase III OU2-Lower Volcano and the Construction Completion Report Early Action Phases I and II Operable Unit 2-Upper and Lower Volcanoes, the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that the concentration of hazardous constituents remaining in the soil (if any) within the boundaries of SWMU Nos. 10 and 11 do not pose an unacceptable risk to human health or the environment since they are below the remediation goals approved in the Operable Unit 2 – Upper and Lower Volcanoes Construction Work Plan for residential/unrestricted use and protection of groundwater. No Further Action is required for these SWMUs. The U.S. EPA concurs with these decisions.

The results of soil sampling performed as part of the confirmation sampling for the Volcanoes early action indicate that there are several areas within the Engineering Propulsion Laboratory (EPL) General Area (SWMU No. 31), outside of the boundaries of the Upper and Lower Volcanoes, where the concentrations of polychlorinated biphenyls (PCBs) are above the residential/unrestricted use SROs, but below the industrial SROs. The areas that will be specifically incorporated into future activities at the EPL General Area (SWMU No. 31)are identified as grid locations: L9, T-13 – T-15, Q15, M16, G18, H19, G20, J22, K22, E23 – I23, G24, H24, G27, G29 and F31 near the Lower Volcano and 225, 123, A16, A21, A22, D16, D20, F18, G18, G22, H12, U14, S10 and T10 near the Upper Volcano. If, at the completion of RCRA corrective action activities within the EPL General Area, the concentration of PCBs in the soil at these grid locations still exceeds the residential/unrestricted use SROs, then the Division will require implementation of an enforceable institutional control to ensure that the land use in this area remains consistent with the assumptions used to develop the industrial use scenario soil remediation objectives.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report and the Early Action Construction Completion Report and Addendum for SWMU Nos. 10 and 11 to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call me at (303) 692-3348 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Charles G. Johnson

Charles G. Johnson
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Mr. Corey Lam, U.S. Air Force Wright Patterson AFB
William Bath, Lockheed Martin Space Systems
Marsha Bates, Shaw Group Environment and Infrastructure
David Rathke, EPA
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department
~~William Allison~~, AGO
Walter Avramenko, CDPHE
Dave Walker CDPHE

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Bill Owens, Governor
Dennis E. Ellis, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department of Public Health and Environment

August 2, 2006

CERTIFIED MAIL NO: 7005 1820 0000 3205 1626
Return Receipt Requested

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Approval of the Combined Soils Units Interim Corrective Measures Remedial Construction Completion Report, Compliance Order on Consent 98-10-08-01, Former U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) evaluated your April 27, 2006 Combined Soils Units Interim Corrective Measures Remedial Construction Completion Report (Construction Completion Report) and requested several minor revisions to the document. The revised Construction Completion Report was submitted on June 21, 2006. Since the document included proposed final Remedial Actions/Corrective Measures for 15 Solid Waste Management Units (SWMUs) at the Former Air Force Plant PJKS, the Division issued the revised Construction Completion Report for a 30-day public comment period on June 28, 2006. We received only one set of written comments on the Construction Completion Report. The commenter requested several minor clarifications to the text of the document and the modifications that will address the comments are listed below. However, since the response to comments does not entail any changes to the proposed final Remedial Actions/Corrective Measures for the Former Air Force Plant PJKS, the Division is hereby approving the Construction Completion Report with the five (5) minor modifications listed below. The final Remedial Actions/Corrective Measures proposed in the Construction Completion Report are effective upon your receipt of this correspondence. U.S. EPA Region 8 concurs with this determination. Please provide revised pages of the Construction Completion Report within one hundred and twenty (120) days of your receipt of this letter to ensure that a complete document is available for the public record.

1. Section 5.1, Page 5-2 – Please modify the second paragraph of the "Restricted Site Closure" subsection to reference a new Appendix that includes general information regarding the Colorado Environmental Covenant Law. Please ensure that the new appendix includes a copy of Colorado Senate Bill 01-145 (Effective July 1, 2001), the January 2002 Senate Bill 01-145 Public Guidance Document and Revision 3.0 of the Environmental Covenant Standard Language. A hard copy of each of these documents is provided in Attachment 1 of this correspondence and electronic versions will be provided to you via email.

2. Section 5.1, Page 5-2 – Please modify the second paragraph of the "Restricted Site Closure" subsection to clearly state that the environmental covenant will be placed on **all** of the property that comprises the PJKS site.

3. Section 5.1, Page 5-2 – Please add a statement at the end of this section that acknowledges that even though only 15 of the 53 total soil related SWMUs at the PJKS site actually require an environmental covenant to maintain engineering controls and/or restrict land use, the property owner LMSSC has determined that a non-residential landuse restriction will be applied to the entire property that encompasses the PJKS site for ease of implementation of the environmental covenant.

4. Figure Nos. 3 and 9 - Please revise Figure Nos. 3 and 9, or provide additional figures at the same scale, that clearly show the areas where the existing asphalt or concrete covers will have to be maintained as part of the PJKS environmental covenant. Provide an additional figure, to the same scale as Figure Nos. 3 and 9, that delineates the area within SWMU 31, around sample location 2UV017-SW, where long-term maintenance of the asphalt cover is required.

5. Abbreviations and Acronyms, Page vii – Please include definitions for the abbreviations "LUC" (Land Use Control) and "cy" (cubic yard).

As noted in Section 5.1 of the Construction Completion Report, an enforceable institutional control will be required to ensure continued protectiveness of the remedial action/final corrective measure for soil at 15 of the SWMUs at the Former Air Force Plant PJKS. The enforceable institutional control that will be required by the Division is an environmental covenant pursuant to section 25-15-320 of the Colorado Revised Statutes. The environmental covenant for the Former Air Force Plant PJKS will specify that the entire property that comprises the PJKS site will be restricted to non-residential uses and that the existing asphalt or concrete covers in small portions of SWMU Nos. 12, 29 and 31 will be properly maintained in perpetuity. The three areas requiring asphalt or concrete covers to ensure continued protection of human health will be incorporated into the existing site excavation permit program to ensure that cover and soil disturbing activities will be conducted by properly trained and equipped workers. The current property owner, Lockheed Martin Space Systems Company (LMSSC), has approved of, agreed to abide by, and agreed to implement, these land-use restrictions and engineering controls as part of the final remedial action/final corrective measure for the Former Air Force Plant PJKS site.

Division policy dated January 9, 2006 (See Attachment 2) requires that a signed environmental covenant be submitted to the Division within 30-days of the remedial decision for remedies that rely solely on the use of engineering and institutional controls. However, the Division is granting additional time to complete the Former Air Force Plant PJKS environmental covenant due to need to negotiate the specific covenant language among three parties. The Division will begin preparing an initial draft of the Former Air Force Plant PJKS environmental covenant within 30-days with the intent of having LMSSC submit the signed environmental covenant within 270-days of receipt of this correspondence.

- Identification of the entity that will perform the inspections;
- A checklist that identifies the areas and items to be inspected and the criteria for determining whether an unauthorized/improper disturbance has occurred or if maintenance actions are required;
- A description of the general actions to be taken in the event that a deficiency is identified.
- A survey of the location and size of the areas requiring asphalt/concrete covers for use in the
- Figures showing the size and location of the areas requiring asphalt/concrete covers (See modification No. 4 above);
- A commitment to submit an operation and maintenance status report, as required by Section 14.2 of the Scope of Work for Consent Order 98-10-08-01, to the Division on an annual basis.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence or Mr. David Kreutzer of the Colorado Attorney Generals Office at (303) 866-5667 for legal inquiries.

Sincerely,

David Walker

David Walker
Hazardous Waste Corrective Action Unit
Compliance Program

cc: All Without Attachment
David Rathke, EPA
Noreen Okubo, EPA
Vicki Anderson, Lockheed Martin Space Systems Co.
Patrick McGinnis, Shaw Environmental Inc.
Roy Laws, Jefferson County Health Department
David Kreutzer, AGO
Walter Avramenko, CDPHE

DO#37
R2.1.5

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

Laboratory Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department of Public Health and Environment

June 23, 2005

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Approval With Modifications of the Combined Soils Additional Investigation Report and Decision on Petitions for No Further Action For Solid Waste Management Unit Nos.16, 18, 19, 20, 21, 23 through 26 and 32 through 35, Compliance Order on Consent 98-10-08-01, U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your April 21, 2005 Combined Soils Additional Investigation Report for Combined Soils Units (Combined Soils RFI Report) and the associated Petition for No Further Action for Solid Waste Management Unit (SWMU) Nos. 16, 18, 19, 20, 21, 23, 24,25, 26, 32, 33, 34 and 35.

Based on the information provided in the Combined Soils RFI Report and Sections 5 through 8 of the Supplemental Remedial Investigation (SRI) Report, Volume II (dated September 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We are approving the Combined Soils RFI Report with the four modifications listed below. U.S. EPA Region 8 concurs with this determination. Please provide revised pages of the Combined Soils RFI Report within one hundred and twenty (120) days of your receipt of this letter.

1. Solid Waste Management Unit (SWMU) No. 22, D-4 Test Stand – Please modify the Combined Soils RFI Report to indicate that the surface soil samples from SWMU 22 locations 3-B106, 3-B177, 3-B178, D4TS04 and D4TS05 were collected from directly beneath or adjacent to asphalt roadways. It is the Division's belief that the elevated concentrations of polyaromatic hydrocarbons (PAHs) detected in these samples are likely related to the tar component of the asphalt and not from PJKS waste management activities. Therefore, please also modify the Combined Soils RFI Report to indicate that the area encompassing these borings will not be carried through to the Corrective Measures Study (CMS) phase for the D-4 Test Stand. This modification effects Section 7.1.12.1 (page 7-11, first paragraph), Section 8.1.10.1 (page 8-4, second paragraph) and Table 38 (page 3 of 5). Please note that SWMU No. 22, the D-4 Test Stand, will continue into the CMS phase to address the PAH contamination detected in the D-4 Test Stand winch pit.

2. Section 7.1.12.1, page 7-11, paragraph 2 – Please modify the text and Figure 18 of the Combined Soils RFI Report to clearly indicate that the reanalysis of the surface soil at SWMU 22 location 3-SS22 confirmed that the polychlorinated biphenyl (PCB) aroclor 1254 was present in surface soil, but at much lower concentrations then found in the original analysis. No further action is required for the PCB 1254 in this surface soil location since the concentration is below the residential soil remediation objective.

3. Section 7.1.12.1, page 7-11 – Please modify the text and Figure 18 of the Combined Soils RFI Report to clearly indicate that the reanalysis of the surface soil at SWMU 22 location 3-SS8 confirmed the presence of benzo(a)pyrene in surface soil, but at much lower concentrations then found in the original analysis. No further action is required for the benzo(a)pyrene in this surface soil location since the concentration is below the residential soil remediation objective. Please also strike the third sentence of the second paragraph of Section 8.1.10.1 since the PAH contamination in the surface soil at the base of the concrete firing apron was not confirmed.

4. Section 8.1.11 T-8 Drainage Flumes (SWMU No. 15), Eastern End Exposure Area II, pages 8-5 and 8-6 and Table 36, page 2 of 2 – In discussions with Mr. Thomas Cooper of Shaw Environmental since the Combined Soils RFI Report was submitted, it appears that the reasonable exposure concentration (REC) for detected constituents in Exposure Area II were not calculated correctly. Please modify the appropriate text and tables of the Combined Soils RFI Report to incorporate the correctly calculated RECs for each constituent detected in Exposure Area II.

   This issue is particularly important for the benzo(a) pyrene (BAP) REC for all soil depths and the dibenzo(a,h)anthracene (DAHA) REC for surface soil since the originally calculated RECs were above the Tier 2 Industrial Soil Remediation Objectives. Based on a June 23, 2005 teleconference with Mr. Thomas Cooper of Shaw Environmental, the correct DAHA REC for Exposure Area II surface soil is 130 ug/kg, which is actually below the Tier 2 Industrial Soil Remediation Objective. In addition, the corrected RECs for all other constituents throughout Exposure Area II, except BAP, are still below the Tier II Industrial Soil Remediation Objectives. The corrected BAP REC for Exposure Area II all soil depths is 204 ug/kg which is only slightly above the Tier 2 Industrial Soil Remediation Objective. Considering that REC exceedence of the Tier 2 Industrial Soil Remediation Objective was based on a single detection of BAP above the standard, with no other detections of BAP in any of the other Exposure Area II soil samples, we concur with your conclusion in Table 38 (page 4 of 5) that no further action is required for BAP in Exposure Area II. As a result, T-8A Drainage Flumes, Eastern End Exposure Area II should not be carried through to the CMS phase.

As required by Paragraphs 22.b and 25 and Section 5.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, a Corrective Measure Study must be performed for SWMU Nos. 12, 13, 15, 17, 22, 29, and 31. The Division notes that the Corrective Measures Study Report for these SWMUs was submitted concurrently with the Combined Soils RFI Report on April 21, 2005. The Division and U.S. EPA evaluation of the Corrective Measure Study Report will be provided in separate correspondence.

The information provided in the Combined Soils RFI Report and the SRI Report also provided the basis for our determination that the concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 16, 18, 19, 20, 21, 23, 24, 25, 26, 32, 33, 34, and 35 do not pose an unacceptable risk to human health or the environment since they are below the Division's residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. U.S. EPA Region 8 concurs with this determination.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the Combined Soils RFI Report to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence or Mr. David Kreutzer of the Colorado Attorney Generals Office at (303) 866-5667 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: David Rathke, EPA
Noreen Okubo, EPA
Vicki Anderson, Lockheed Martin Space Systems Co.
Patrick McGinnis, Shaw Environmental Inc.
Roy Laws, Jefferson County Health Department
David Kreutzer, AGO
Dave Walker, CDPHE

D031
R2.1.5

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department of Public Health and Environment

April 3, 2003

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Comments on Section 7, OU3 – Test Stands and Deluge Systems and Section 8, OU6 – Ordnance Testing Laboratory- of the Supplemental Remedial Investigation Report, U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has reviewed and is commenting on all Subsections of Section 7 except 7.4 (D-1 Landfill) and 7.15 (T-31 Chemical Treatment Facility), and all of Section 8, of the Supplemental Remedial Investigation (SRI) Report regarding Operable Unit 3 – Test Stands and Deluge Systems (OU3) and Operable Unit 6 – Ordnance Testing Laboratory (OU6). The attached comments also incorporate the U.S. EPA comments regarding these subsections of the SRI Report. Response to the attached comments must be received by the Division within one hundred and twenty (120) days of your receipt of this letter. Please call Mr. Dave Walker at (303) 692-3354 if you have any questions, or would like to request a meeting, regarding this correspondence.

Based on our evaluation of Subsection 7.18 (Riprap Area North of T-8A Containment Pond) of the Supplemental Remedial Investigation Report, Volume III (dated December 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil at the Riprap Area North of T-8A Containment Pond (SWMU No. 27) do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for this SWMU. U.S. EPA Region 8 concurs with this determination.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report for SWMU No. 27 to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Sincerely,

Walter Avramenko, Unit Leader
Hazardous Waste Cleanup and Permitting Unit
Compliance Program

cc: Dave Walker, CDPHE
William Allison, AGO
Charles Johnson; CDPHE
David Rathke, EPA
Felix Flechas; EPA
Bill Bath, Lockheed Martin Astronautics
Marsha Bates, Shaw Environmental and Infrastructure ✓
Roy Laws, Jefferson County Health Department

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department
of Public Health
and Environment

August 29, 2002

CERTIFIED MAIL NO: 9656 7271
Return Receipt Requested

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Comments on Section 6, OU2 – Engineering Propulsion Laboratory Characterization - of the Supplemental Remedial Investigation Report, U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has reviewed and is commenting on Section 6 of the Supplemental Remedial Investigation (SRI) Report regarding Operable Unit 2 – Engineering and Propulsion Laboratory (OU2). The attached comments also incorporate the U.S. EPA comments regarding this section of the SRI Report. Response to the attached comments must be received by the Division within one hundred and twenty (120) days of your receipt of this letter. Please call Mr. Dave Walker at (303) 692-3354 if you have any questions, or would like to request a meeting, regarding this correspondence.

9/3/02

Based on our evaluation of Section 6.9 (Riprap Area West of Central Support Building T-17) of the Supplemental Remedial Investigation Report, Volume II (dated September 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil at the Riprap Area West of Central Support Building T-17 (SWMU No. 28) do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for this SWMU. U.S. EPA Region 8 concurs with this determination.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report for SWMU No. 28 to all individuals on the facility mailing list within fifteen (15) calender days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Sincerely,

Walter Avramenko, Unit Leader
Hazardous Waste Cleanup and Permitting Unit
Compliance Program

cc: Dave Walker, CDPHE
William Allison, AGO
Charles Johnson; CDPHE
David Rathke, EPA
Felix Flechas; EPA
Bill Bath, Lockheed Martin Astronautics
Marsha Bates, Stone and Webster Environmental Technology and Services
Roy Laws, Jefferson County Health Department

D026
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STATE OF COLORADO

Bill Owens, Governor
Douglas H. Benevento, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

Laboratory Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 0124 1061
Return Receipt Requested

November 4, 2003

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Approval With Modifications of Additional Investigation Report for the Systems and Components Areas and Decision on Petition for No Further Action For Solid Waste Management Unit Nos. 30 and 36 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated the Additional Investigation Report for the Systems and Components Areas (Investigation Report). I am hereby approving the Investigation Report with the three modifications specified below. The U.S. EPA concurs with this decision.

1. Section 4.4.3 (page 4-3, paragraph 3, first bullet) shall be revised to state that Boring SCA005 is not bound to the east since the soil samples collected from Boring 1-B22 were not analyzed for PCBs;
2. Section 5.0 (page 5-1, second major bullet, third sub-bullet) shall be revised to state that the horizontal extent of PCB exceedance to the east of Boring SCA005 has not been defined; and
3. Section 6.0 (page 6-1, first major bullet, second sub-bullet) shall be revised to add the words "and west" after the word south.

Please provide the revised pages of the Investigation Report within one hundred and twenty (120) days of your receipt of this letter.

The Division has also evaluated your Petition for No Further Action for Solid Waste Management Unit (SWMU) Nos. 30 and 36 September 19, 2003. Based on the information provided in Investigation Report and Section 5 of the Supplemental Remedial Investigation Report, the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01 for SWMU Nos. 30 and 36. We have also determined that concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 30 and 36 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. The U.S. EPA concurs with these decisions.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: William Bath, Lockheed Martin Space Systems
Marsha Bates, Shaw Environment Inc.
David Rathke, EPA
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department
William Allison, AGO
Charles G. Johnson, CDPHE
Dave Walker CDPHE

UU 5 !
R2.1.5

STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department
of Public Health
and Environment

CERTIFIED MAIL No. 0122 3920
Return Receipt Requested

April 22, 2003

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Approval of RFI Report and Decision on Petition for No Further Action For Solid Waste Management Unit Nos. 37, 38, 39, 40, and 41 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Lam:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated the RCRA Facility Investigation Report for Solid Waste Management Unit Group G (RFI Report) and your Petition for No Further Action for Solid Waste Management Unit (SWMU) Nos. 37 through 41 (a.k.a. SWMU Group G) dated March 13, 2003. Based on the information provided in RFI Report, the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 37 through 41 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. The U.S. EPA concurs with these decisions.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: William Bath, Lockheed Martin Space Systems
Marsha Bates, Shaw Environmental and Infrastructure
David Rathke, EPA
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department
William Allison, AGO
Charles G. Johnson, CDPHE
Dave Walker CDPHE

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Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 2457 6590
Return Receipt Requested

February 24, 2003

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Decision on Petitions for No Further Action For Solid Waste Management Unit Nos. 42 and 47 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your February 18, 2003 RCRA Facility Investigation Report for Solid Waste Management Unit Group H (SWMU Group H RFI Report) and associated Petition for No Further Action for Solid Waste Management Unit (SWMU) No. 42 (the T-20A Compressor House) and SWMU No. 47 (Tank MM7, Building T-23). Based on the information provided in the SWMU Group H RFI Report, the No Further Response Action Planned Document for SWMU No. 47 (dated October 1992), Section 2.4 (pages 2-2 to 2-10) of the RCRA Facility Investigation Work Plan for Solid Waste Management Unit Group H (dated September 27, 1999) and Section 6.2 of the Supplemental Remedial Investigation Report, Volume II (dated September 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 42 and 47 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. U.S. EPA Region 8 concurs with this determination.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calender days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Charles G. Johnson, CDPHE
William Allison, AGO
David Rathke, EPA
Dave Walker CDPHE
Felix Flechas, EPA
Mr. Corey Lam, U.S. Air Force Wright Patterson AFB
William Bath, Lockheed Martin Space Systems
Marsha Bates, Stone and Webster
Roy Laws, Jefferson County Health Department

D012
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STATE OF COLORADO

Bill Owens, Governor
Jane E. Norton, Executive Director

Dedicated to protecting and improving the health and environment of the people of Colorado

4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department
of Public Health
and Environment

CERTIFIED MAIL No. 2452 3808
Return Receipt Requested

November 29, 2001

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Decision on Petitions for No Further Action For Solid Waste Management Unit Nos. 43, 44, 45, and 46 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your Petitions for No Further Action for Solid Waste Management Unit (SWMU) No. 43 (the T-28D Equipment Room Floor Drain), SWMU No. 44 (the Central Support Storage Area: T-17), SWMU No. 45 (the Pump Pit #2), and SWMU No. 46 (the Missile Storage Building Drain: T-42). Based on the information provided in the No Further Response Action Planned Documents for each of these SWMUs (dated October 1992), Section 2.4 (pages 2-5 to 2-9) of the RCRA Facility Investigation Work Plan for Solid Waste Management Unit Group H (dated September 27, 1999) and Sections 5.2.5, 6.2, 7.17, and 8.0 of the Supplemental Remedial Investigation Report, Volume II (dated September 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 43, 44, 45, and 46 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. U.S. EPA Region 8 concurs with this determination.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calender days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Charles G. Johnson, CDPHE
William Allison, AGO
David Rathke, EPA
Dave Walker CDPHE
Felix Flechas, EPA
Mr. Corey Lam, U.S. Air Force Wright Patterson AFB
William Bath, Lockheed Martin Space Systems
Marsha Bates, Stone and Webster
Roy Laws, Jefferson County Health Department

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
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Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

http://www.cdphe.state.co.us

Colorado Department of Public Health and Environment

CERTIFIED MAIL No. 9649 7073
Return Receipt Requested

January 7, 2003

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Decision on Petition for No Further Action For Solid Waste Management Unit Nos. 48, 50, 51,52, 53, 54, 55, and 56 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your Petition for No Further Action for Solid Waste Management Unit (SWMU) Nos. 48 and 50 through 56 (a.k.a. SWMU Group I). Based on the information provided in the No Further Response Action Planned Documents for Underground Storage Tank EPA Registration No. 6, (IRP Site ST-36), No. 8 (IRP Site ST-24), No. 9 (IRP Site ST-25), No. 11 (IRP Site ST-16), No.12 (IRP Site ST-26), No. 13 (IRP Site ST27) and No. 14 (IRP Site ST-28) (all dated October 1992) and the RCRA Facility Investigation Report for Solid Waste Management Unit Group I (dated December 11, 2002), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil (if any) at SWMU Nos. 48 and 50 through 56 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for these SWMUs. The U.S. EPA concurs with these decisions.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calendar days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary and the fact that this will be the first such RFI summary developed, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries.

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Mr. Corey Lam, U.S. Air Force Wright Patterson AFB
William Bath, Lockheed Martin Space Systems
Marsha Bates, Stone and Webster
David Rathke, EPA
Felix Flechas, EPA
Roy Laws, Jefferson County Health Department
William Allison, AGO
Charles G. Johnson, CDPHE
Dave Walker CDPHE

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Bill Owens, Governor
Jane E. Norton, Executive Director

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4300 Cherry Creek Dr. S.
Denver, Colorado 80246-1530
Phone (303) 692-2000
TDD Line (303) 691-7700
Located in Glendale, Colorado

http://www.cdphe.state.co.us

Laboratory and Radiation Services Division
8100 Lowry Blvd.
Denver, Colorado 80230-6928
(303) 692-3090

Colorado Department
of Public Health
and Environment

CERTIFIED MAIL No. 2452 4188
Return Receipt Requested

October 24, 2001

Mr. Karl Kunas
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH

RE: Decision on Petition for No Further Action For Solid Waste Management Unit No. 49, Tank MM4, Building T-6 Located at United States Air Force Plant PJKS: CO 7570090038

Dear Mr. Kunas:

The Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) has evaluated your Petition for No Further Action for Solid Waste Management Unit (SWMU) No. 49, Tank MM4, Building T-6. Based on the information provided in the No Further Response Action Planned Document for Underground Storage Tank EPA Registration No. 4, IRP Site ST-13 (dated October 1992), Section 2.4 (page 2-4) of the RCRA Facility Investigation Work Plan for Solid Waste Management Unit Group I (dated June 28, 1999) and Section 6.2 of the Supplemental Remedial Investigation Report, Volume II (dated September 1998), the Division has determined that the Air Force has fulfilled the requirements for performing a RCRA Facility Investigation of Paragraph 22.a and Section 4.0 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01. We have also determined that concentration of hazardous constituents remaining in the soil at SWMU No. 49 do not pose an unacceptable risk to human health or the environment since they are below the Division's draft residential/unrestricted use and protective of groundwater soil remediation objectives and that No Further Action is required for SWMU 49, Tank MM4, Building T-6.

In accordance with Section 4.3.4 of the Scope of Work of Compliance Order On Consent No. 98-10-08-01, the Air Force must mail a short summary of the RFI Report to all individuals on the facility mailing list within fifteen (15) calender days of receipt of this letter. In accordance with Section 4.3.2 of the order Scope of Work, the Division will review and comment on the RFI summary prior to the mailing. Due to time required for the Division to review the RFI summary and the fact that this will be the first such RFI summary developed, the Division is hereby granting a 30-day extension for the mailing of the RFI summary. The RFI summary must be mailed within forty-five (45) days of receipt of this letter.

Please call Dave Walker at (303) 692-3354 for technical questions regarding this correspondence and Mr. William Allison of the Colorado Attorney Generals Office at (303) 866-5361 for legal inquiries..

Sincerely,

Walter Avramenko
Unit Leader
Hazardous Waste Corrective Action Unit
Compliance Program

cc: Charles G. Johnson, CDPHE
William Allison, AGO
David Rathke, EPA
Dave Walker CDPHE
Felix Flechas, EPA
Mr. Corey Lam, U.S. Air Force Wright Patterson AFB
William Bath, Lockheed Martin Space Systems
Marsha Bates, Stone and Webster
Roy Laws, Jefferson County Health Department

APPENDIX B

GROUNDWATER RAO LETTERS

Colorado Department
of Public Health
and Environment

January 25, 2006

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Corrective Action Objectives for PJKS Groundwater Contamination Source Areas, Compliance Order on Consent 98-10-08-01, U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Lam:

This correspondence provides a response from the Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) and U.S. EPA Region 8 (the Agencies) to your December 7, 2005 inquiry regarding corrective action objectives for Air Force Plant PJKS. The Agencies have evaluated the need for consistency between ongoing groundwater corrective measures at Lockheed Martin Space Systems Company (LMSSC) facility and those being requested by the regulators for the former Air Force Plant PJKS site. Specifically, we evaluated the rationale for the Agencies to request that the Air Force perform active treatment and/or containment of groundwater contamination source areas on the PJKS site, while LMSSC has not been required to actively treat and/or contain areas on their property that appear to have similar source area characteristics.

The Division is in the process of evaluating the overall performance of LMSSC's remedy and the need to conduct additional remediation within the groundwater source areas (e.g., in the vicinity of the Inactive Site). However, based on information the Agencies have received during various meetings with both LMSSC and the Air Force, we understand that there is disagreement regarding the actual source of the contaminants in the groundwater near LMSSC's Inactive site that appear to be acting as a source area for alluvial groundwater on LMSSC property. It is also our understanding that the Air Force and LMSSC are making progress toward conducting additional groundwater investigations that may provide an answer to the actual source(s) of groundwater contamination near the Inactive Site. The Division has determined that a decision regarding the need for additional "source area remediation measures" for the highly contaminated groundwater on LMSSC property can be delayed until the additional investigations have been completed.

The Agencies have determined that we will require the Air Force to continue with their plans to conduct active corrective action/remediation at the PJKS groundwater contamination source areas in an effort to reduce the source mass of the contamination with the intent to eventually reduce the concentration of contaminants in groundwater exiting the PJKS site. The Agencies are aware that this goal may not be achievable using currently available technologies, but we will require that an effort be made if a viable remedial technology becomes available (e.g., one of the technologies currently undergoing bench and pilot scale testing).

At this time, the Agencies, the Air Force and LMSSC agree that the installation and operation of a system intended to collect and/or treat the groundwater contamination plume(s) as they exit the PJKS site and enter LMSSC property is not a logical use of available financial resources and will not result in a reduction in the amount of time required to cleanup the groundwater at the PJKS site. However, the continued flow of groundwater contamination from the PJKS site onto LMSSC property negatively impacts LMSSC's ability to comply with the Record of Decision guiding their cleanup effort. As a result, the Agencies have determined that we will require the installation and operation of a PJKS boundary control system in the event that the Air Force is reluctant to conduct active source area corrective measures on PJKS property.

The intent of this correspondence is to clarify the Agencies position regarding corrective action objectives for the PJKS site so that the Air Force may plan appropriately. Please call Mr. David Walker at (303) 692-3354, or Mr. David Rathke at (303) 312-6016 if you have any questions regarding this correspondence.

Sincerely,

David Walker

David Walker
Colorado Department of Public Health
Health and Environment

David Rathke

David Rathke
U.S. Environmental Protection
Region VIII

cc: Terry Anderson, U.S. EPA Region VIII
Vicki Anderson, Lockheed Martin Space Systems Co.
Patrick McGinnis, Shaw Environmental Inc.
Roy Laws, Jefferson County Health Department
Colleen Brisnehan, CDPHE/HMWMD
Walter Avramenko, CDPHE/HMWMD
David Kreutzer, AGO

Colorado Department
of Public Health
and Environment

February 8, 2006

Mr. Corey Lam
Environmental Restoration Manager
U.S. Air Force Aeronautical Systems Center
Wright Patterson AFB
Dayton, OH 45433-7626

RE: Incorporation of Groundwater Interim Actions/Interim Corrective Measures into the final Record of Decision/Corrective Measures Selection for former Air Force Plant PJKS, Compliance Order on Consent 98-10-08-01, U.S. Air Force Plant PJKS: CO7570090038

Dear Mr. Lam:

This correspondence is a follow-up to the January 25, 2006 correspondence from the Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division (the Division) and U.S. EPA Region 8 (the Agencies) regarding corrective action objectives for Air Force Plant PJKS. Specifically, you requested clarification of whether the interim action/interim corrective measure currently planned for several bedrock groundwater source areas at the former PJKS will be incorporated into the final Record of Decision/Corrective Measure selection for the site.

The in-situ bioremediation technology for treating organic solvents in groundwater was shown to be effective during pilot scale testing in the Precambrian bedrock groundwater in the D-1 Landfill area of PJKS. Based upon the success of the pilot test you have proposed to apply the technology on a larger scale as an interim action/interim corrective measure in two areas of the site with similar hydrogeology. If the technology continues to be effective, the Agencies will support directly incorporating the in-situ bioremediation techniques planned as interim actions/interim corrective measures in the bedrock groundwater contaminant source areas into the final corrective measure for the site. This approach is consistent with the CERCLA and RCRA front-end technical impracticability (TI) waiver process that will generate the performance data necessary to support a TI waiver in the groundwater Record of Decision/Corrective Measure for the site. Specifically, the TI waiver will acknowledge that the selected groundwater remedy will have the goal of reducing groundwater contaminant source area concentrations without specifying a goal of achieving state of Colorado groundwater standards in the bedrock aquifers. This approach is consistent with the overall reduction of contaminant concentrations in the groundwater medium outlined in our previous correspondence to you dated January 25, 2006.

Please note that based on the currently available performance monitoring data for the in-situ bioremediation pilot study, the interim action/interim corrective measure is likely to be effective for only the organic solvent portion of the PJKS groundwater contamination. If the additional pilot studies currently planned identify an effective NDMA source area treatment technology, the Agencies will support a phased approach for NDMA similar to the approach used for organic solvents. The final Record of Decision/Corrective Measure selection will also have to incorporate a technology(ies) to address the n-Nitrosodimethylamine (NDMA) groundwater contaminant source and/or distal plume areas.

Please call Mr. David Walker at (303) 692-3354, or Mr. David Rathke at (303) 312-6016 if you have any questions regarding this correspondence.

Sincerely,

David Walker

DMW. for David Rathke

David Walker
Colorado Department of Public Health
Health and Environment

David Rathke
U.S. Environmental Protection
Region VIII

cc: Terry Anderson, U.S. EPA Region VIII
Vicki Anderson, Lockheed Martin Space Systems Co.
Patrick McGinnis, Shaw Environmental Inc.
Roy Laws, Jefferson County Health Department
Colleen Brisnehan, CDPHE/HMWMD
Walter Avramenko, CDPHE/HMWMD
David Kreutzer, AGO

APPENDIX C

GROUNDWATER TREATMENT STUDIES REPORT

(PDF on CD-ROM)

GROUNDWATER TREATMENT STUDIES REPORT
N-NITROSODIMETHYLAMINE WITH TRICHLOROETHENE
(CDRL A001D)

FORMER AIR FORCE PLANT PJKS
WATERTON CANYON, COLORADO

REVISION 1

Prepared for:

Air Force Center for Engineering and the Environment
3300 Sidney Brooks
Brooks City-Base, Texas 78235-5112
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Prepared by:

Shaw Environmental, Inc.
7604 Technology Way
Suite 300
Denver, Colorado 80237

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ABBREVIATIONS AND ACRONYMS

AFCEE	The Air Force Center for Engineering and the Environment
ARAR	applicable or relevant and appropriate requirement
ARD	anaerobic reductive dechlorination
Bioremediation Work Plan	*Bench-Scale Study Work Plan, In Situ Bioremediation of Trichloroethene and N-Nitrosodimethylamine in Alluvial Groundwater*
°C	degrees Celsius
CBSG	Colorado Basic Standards for Groundwater
CDPHE	Colorado Department of Public Health and the Environment
cis 1,2-DCE	*cis* 1,2 dichhlorethene
CSM	conceptual site model
DCE	dichloroethene
Dhc.	Dehalococcoides
DO	dissolved oxygen
Envirogen	Envirogen, Inc.
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
ft^2	square foot (feet)
gal	gallon(s)
g/L	gram(s) per liter
gpm	gallon(s) per minute
HRC®	Hydrogen Release Compound®
ICM	interim corrective measure
IRP	Installation Restoration Program
ITRC	Interstate Technology & Regulatory Council
L	liter(s)
L/hr/g	liter(s) per hour per gram
Lockheed Martin	Lockheed Martin Space Systems Company
μg/L	microgram(s) per liter
mg/L	milligram(s) per liter
mL/hr	milliliter(s) per hour
NDMA	*n*-nitrosodimethylamine
Ni	nickel
Nickel Catalyst Work Plan	*Treatability Test Work Plan, Nickel Catalyst Technology for Ex Situ Treatment of N-Nitrosodimethylamine and Trichloroethene in Groundwater*
nm	nanometer(s)
NSF	National Science Foundation
Order on Consent	*Compliance Order on Consent Number 98-10-08-01*
Parsons	Parsons Engineering Science, Inc.
PJKS	former Air Force Plant PJKS
PQL	practical quantitation limit
PRB	permeable reactive barrier

ABBREVIATIONS AND ACRONYMS (cont'd)

psig	pounds per-square-inch gauge
RCRA	Resource Conservation and Recovery Act
SBIR	Small Business Innovative Research
Shaw	Shaw Environmental, Inc.
Shaw Lawrenceville Laboratory	Shaw's Biotechnology Development and Application Group Laboratory Facilities, Lawrenceville, New Jersey
STL-Denver	Severn-Trent Laboratories, Arvada, Colorado
System	Field Demonstration System
t	time
TCE	trichloroethene
UV	ultra violet
VOC	volatile organic compound
ZVI	zero-valent iron

EXECUTIVE SUMMARY

Twenty-two years of comprehensive field investigations conducted by the U.S. Air Force have determined that trichloroethene (TCE) and *n*-nitrosodimethylamine (NDMA) are the groundwater contaminants of concern at the former Air Force Plant PJKS (PJKS). While NDMA and TCE contamination usually occur simultaneously at PJKS, this report focuses on NDMA contamination because an in situ technology, anaerobic reductive dechlorination (ARD), which has been proven to be effective at remediating TCE groundwater contamination, does not treat NDMA.

This report presents the PJKS groundwater contamination conceptual site model; history of groundwater treatment strategies for TCE and NDMA; description of full-scale interim corrective measures; literature research of theoretical, bench-scale, and field-scale NDMA groundwater treatment technologies; and results of the implementation of PJKS-specific bench-scale and field demonstration NDMA treatment technologies.

Two technologies were investigated during the bench-scale studies: one, an in situ bioremediation technology, employing naturally occurring and exogenous bacteria capable of mineralizing NDMA; another, an ex situ nickel catalyst technology designed to decompose NDMA into innocuous daughter products. The bioremediation technology failed to produce satisfactory results; however, the nickel catalyst bench-scale results were sufficient to warrant a field demonstration.

The year-long nickel catalyst field demonstration produced mixed results. Initial NDMA degradation rates appeared promising; however, as the field demonstration progressed, problems with nickel catalyst corrosion, membrane filter fouling, general system fouling, nickel present in the treatment effluent, and inexplicable chemical side reactions proved insurmountable and the field demonstration was stopped. The report concludes that ex situ nickel catalyst treatment of NDMA using the operational process designed for the field demonstration is not a feasible technology for PJKS. Results of the literature research conclude that treatment of NDMA with ultra violet light combined with chemical oxidation is the most viable remediation technology available at this time.

1.0 INTRODUCTION

This Groundwater Treatment Studies Report presents the results of bench-scale and field demonstration studies conducted by Shaw Environmental, Inc. (Shaw). The studies evaluated in situ and ex situ strategies for treating low level *n*-nitrosodimethylamine (NDMA) groundwater contamination at the former Air Force Plant PJKS (PJKS). Because NDMA groundwater contamination at PJKS usually occurs in the presence of trichloroethene (TCE) contamination, the studies were conducted using groundwater that contained both NDMA and TCE. So while the focus of the studies was to evaluate NDMA remediation technologies, TCE behavior was also observed and recorded during the trials. TCE and NDMA are the contaminants of concern at PJKS and their mitigation is the basis for the remediation strategies for the site.

Two bench-scale studies were performed. The first evaluated the potential for in situ remediation of NDMA using bioremediation as the treatment technology and the second evaluated ex situ treatment of NDMA using a nickel catalyzed reaction as the treatment technology. The bench-scale studies were conducted at Shaw's Biotechnology Development and Application Group's laboratory facilities in Lawrenceville, New Jersey (Shaw Lawrenceville Laboratory) and were performed as outlined in the *Bench-Scale Study Work Plan, In Situ Bioremediation of Trichloroethene and N-Nitrosodimethylamine in Alluvial Groundwater* (Bioremediation Work Plan) (Shaw, 2004) and the *Treatability Test Work Plan, Nickel Catalyst Technology for Ex Situ Treatment of N-Nitrosodimethylamine and Trichloroethene in Groundwater* (Nickel Catalyst Work Plan) (Shaw, 2005c). A field demonstration followed the successful completion of the ex situ nickel catalyst bench-scale study. Field activities were conducted onsite at PJKS as outlined in the Nickel Catalyst Work Plan.

Shaw conducted the studies and prepared this document under the Air Force Center for Engineering and the Environment (AFCEE) Contract No. F41624-03-D-8615. The Aeronautical Systems Center at Wright-Patterson Air Force Base, Ohio, manages environmental programs at PJKS. The U.S. Air Force owned the PJKS property until February 2001, when ownership was transferred to the Lockheed Martin Space Systems Company (Lockheed Martin), the long-term operator of the facility. PJKS is located on a 464-acre parcel of land in Waterton Canyon, Colorado, and is surrounded by the remainder of the Lockheed Martin industrial facility.

In December 1998, the U.S. Air Force signed an agreement, the *Compliance Order on Consent Number 98-10-08-01* (Order on Consent) (State of Colorado, 1998), with the Colorado Department of Public Health and the Environment (CDPHE), Hazardous Materials and Waste Management Division. All state and federal regulations applicable to PJKS, including Comprehensive Environmental Response, Compensation, and Liability Act, Defense Environmental Restoration Program, Resource Conservation and Recovery Act (RCRA), National Oil and Hazardous Substance Pollution Contingency Plan, and Colorado Hazardous Waste Act, were merged into this agreement. The Order on Consent recognizes CDPHE as the lead regulatory agency for PJKS.

1.1 BACKGROUND

Characterization of groundwater contamination at PJKS was initiated in January 1986 as a result of the promulgation of RCRA and the subsequent Superfund Amendments and Reauthorization

Act. Since then, numerous activities (site characterizations, remedial investigations, interim corrective measures (ICMs), bench-scale studies, and pilot studies) have been conducted to refine the understanding of contaminant distribution in the groundwater system(s) so that the appropriate remedy or remedies can be selected for contaminant mitigation.

The following bibliography lists key investigatory events and study reports:

- *Supplemental Remedial Investigation Report* (Parsons Engineering Science, Inc [Parsons], 1999)
- *Pilot Study Work Plan, Brush Creek/Lariat Gulch Groundwater Plumes* (Shaw, 2003)
- *Bedrock Pilot Study, Supplemental Work Plan, Well Installation and Monitoring, Brush Creek/Lariat Gulch Groundwater Plumes* (Shaw, 2005a)
- *Focused Engineering Evaluation/Cost Analysis, Groundwater Plumes, Interim Corrective Measure* (Shaw, 2005b)
- *2006 Annual Groundwater Report* (Shaw, 2007c)

Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study (Shaw, 2007b)

1.2 CONCEPTUAL SITE MODEL

The PJKS conceptual site model (CSM) has been developed from all of the data collected throughout PJKS's investigational history. A groundwater CSM illustrates the relationship between contaminant sources, release/transport mechanisms, and receptors. The CSM, a graphical representation of what is occurring in the groundwater system, provides the "picture" for assessing contaminant risks and evaluating the effectiveness of remediation technologies to mitigate those risks. Building the CSM has been an iterative process that both guides and reincorporates site characterization data. Modifications may occur if data from ongoing groundwater monitoring and ICMs indicate that the CSM picture has changed.

A detailed description of the CSM, which includes a graphical illustration, is presented in the *2006 Annual Groundwater Report* (Shaw, 2007c). The current CSM iteration is briefly outlined as follows:

- *Type of Contamination*. The type of groundwater contamination at PJKS was determined by evaluating several years of groundwater monitoring data. TCE and NDMA emerged as the most persistent groundwater contaminants.
- *Contaminant Sources*. The locations of sources of PJKS contamination were developed from distribution maps of contaminant concentrations in each of the three groundwater aquifers (alluvial, Fountain, and Precambrian). The maps were overlain on each other to determine the relationship(s) between the distributions of contaminants within the hydrogeologic units. Seven areas with groundwater contaminant plumes were identified.

No soil sources for groundwater contamination have been identified. However, current information suggests that areas of persistent elevated groundwater contamination in the bedrock aquifers act as sources of contamination that have been reported in the alluvial aquifer at downgradient locations. For the purpose of the CSM, these areas are referred to as source areas. Because the seven plume areas are sufficiently similar, the CSM is applied to all plumes.

- *Release/Transport Mechanisms*. Contamination from the bedrock sources migrates into alluvial drainages. Potential pathways of contamination to receptors occur through contact with bedrock and alluvial groundwater and surface water.
- *Receptors*. PJKS is an industrial site with no residential inhabitants or use of groundwater. Therefore, under current conditions, there are no completed exposure pathways to potential human or environmental receptors. Assuming that future land use will remain the same, commercial/industrial workers are identified as potential future human receptors.

1.3 GROUNDWATER TREATMENT PROGRESS

In the many years that groundwater characterization has been conducted at PJKS, significant progress has been made in the environmental cleanup program. Groundwater cleanup strategies focusing on the contaminants of concern (TCE and NDMA) have been studied and implemented. These strategies are discussed in the following sections.

1.3.1 Bedrock Pilot Study

In 2003, a three-year Bedrock Pilot Study was initiated to evaluate the effectiveness of enhanced in situ anaerobic reductive dechlorination (ARD) for the treatment of TCE and NDMA in the bedrock source areas. During the Bedrock Pilot Study, one of two organic treatment substrates (either Hydrogen Release Compound® [HRC®] or sodium lactate) was injected into bedrock aquifers. These substrates serve the purpose of stimulating microbial growth and development, thereby creating an anaerobic environment in which the rate of anaerobic degradation of TCE and NDMA to innocuous end products may be greatly enhanced.

In addition to organic substrate injections, bioaugmentation was investigated. Bioaugmentation consisted of injecting a microbe (Dehalococcoides [Dhc.] ethenogenes), which was cultured on PJKS groundwater sediments, into a TCE-contaminated Fountain Formation source area. Dhc. ethenogenes have demonstrated the ability to completely degrade TCE to ethene.

Evaluation of data collected during the Bedrock Pilot Study determined the following:

- Sodium lactate is a more efficient and cost-effective treatment substrate than HRC®.
- In situ ARD can reduce TCE concentrations in the Precambrian bedrock source areas using injection of sodium lactate.
- In situ ARD can reduce TCE concentrations in the Fountain Formation bedrock source areas, although bioaugmentation is required in addition to sodium lactate injections.
- In situ ARD did not reduce concentrations of NDMA.

Details of the Bedrock Pilot Study are presented in the *Summary and Evaluation Report, Brush Creek/Lariat Gulch Groundwater Plumes Pilot Study* (Shaw, 2007b). The results of the Bedrock Pilot Study led to the implementation of ICMs at the D-1 Area and the D-4 Fuel Storage source areas that are presented in the following section.

1.3.2 D-1 Area and D-4 Fuel Storage Area ICMs

In the summer of 2006, Precambrian aquifer monitoring/injection wells were installed in the D-1 Area (an NDMA and TCE source area) and D-4 Fuel Storage Area (a TCE-only source area). Sodium lactate injections commenced after baseline groundwater conditions were established and a quarterly groundwater monitoring program was initiated to track the rate of in situ ARD treatment of TCE. The results of the quarterly groundwater monitoring events will be used to determine the type (e.g., sodium lactate, nutrients, Dhc. ethenogenes) and periodicity of ongoing amendment injections. Construction completion reports for the D-1/D-4 ICMs are presented in two documents: the *Interim Corrective Measure Remedial Construction Completion Report, D-1 Area Groundwater Plume* (Shaw, 2007d) and the *Interim Corrective Measure Remedial Construction Completion Report, D-4 Fuel Storage Area* (Shaw, 2007e).

1.3.3 Groundwater Source Areas ICMs

In the summer of 2007, fieldwork began on the installation of directional groundwater wells in the Engineering Propulsion Laboratory and Systems and Components Area to facilitate in situ ARD. The fieldwork, which was detailed in the *Implementation Work Plan Groundwater Source Areas Interim Corrective Measure* (Shaw, 2007a), includes the use of sodium lactate, nutrients, and Dehalococcoides (Dhc.) ethenogenes to target TCE contamination in these source areas. Also included in this fieldwork endeavor is the installation of vertical injection wells at the D-1 Tributary, Central Support Storage Area, T-8A Pumphouse, and Ordnance Testing Laboratory to facilitate in situ ARD at these source areas.

2.0 NDMA TREATMENT STATUS

Because treatment technologies that have been successful for TCE groundwater contamination at PJKS have not been successful for NDMA, other technologies were evaluated. Conventional groundwater treatment methods for organic contaminants, including air stripping, absorption on activated carbon, and bacterial degradation have not been effective in removing NDMA. The compound can form and disassociate by different processes. Groundwater treatment processes may successfully disassociate the compound only to have it re-form later. Other contaminants or dissolved constituents in groundwater can affect treatment success. Several different processes and mechanisms have been used, tested, or proposed to treat NDMA-contaminated groundwater, including pump-and-treat methods and in situ methods, with varying degrees of success.

2.1 NATIONWIDE TREATMENT TECHNOLOGIES

The following sections summarize various groundwater treatment processes that have been used, tested, or proposed to remove NDMA from groundwater and wastewater.

2.1.1 Ultra Violet and Ultra Violet Plus Oxidation

Direct photolysis with ultra violet (UV) at 230 nanometers (nm) (with a range from 200 to 260 nm) breaks the nitrogen-to-nitrogen bonds in NDMA and is itself sufficient to destroy the contaminant. Degradation products include dimethylamine, nitrite, and nitrate. The addition of hydrogen peroxide to groundwater prior to UV irradiation is an advanced oxidation technique commonly used in groundwater treatment systems. Concurrent irradiation of the hydrogen peroxide creates an abundance of hydroxyl radicals (•OH) available to oxidize co-contaminants. The addition of hydrogen peroxide, or other oxidants, is not necessary for the destruction of NDMA; however, the use of advanced oxidation techniques likely prevents the re-formation of the NDMA by oxidizing the degradation product nitrite to nitrate (Lem, 1989).

UV plus oxidation has been considered the best available technology for treating NDMA-contaminated groundwater for more than 10 years. Treatment systems are relatively expensive and electrical power-intensive. Groundwater treated with UV oxidation must be pumped, treated ex situ onsite, and then discharged. Treatment systems are manufactured by several industrial suppliers including Calgon, Trojan Technologies, and Komex-WorleyParsons. UV plus oxidation treatment systems in use at remediation sites in California; New Mexico; and Ontario, Canada are processing millions of gallons (gal) of water per day and are typically integrated with other processes treating multiple site contaminants (Lem, 1989).

2.1.2 Incineration

Incineration or thermal oxidation destroys NDMA contaminants in water and has been used as the selected alternative on at least one site (Rocky Mountain Arsenal) for treating waste-process water stored in tanks. Even though UV plus oxidation was considered the best treatment alternative at this site, incineration was selected because no acceptable disposal method was available for the treated process water at that time (Harding Lawson, 1991).

Incineration is not a practical alternative for groundwater remediation when other options are available. As groundwater must be withdrawn from the aquifer for processing, it becomes unavailable for reuse and is lost as vapor to the atmosphere unless additional recovery equipment is used. Incineration is an expensive pump-and-treat groundwater technology with relatively high capital investment and fuel costs.

2.1.3 Hydrous Pyrolysis Oxidation

Hydrous pyrolysis oxidation, or hydrothermal oxidation, was investigated as a potential in situ treatment technology for the destruction of NDMA in groundwater by the Lawrence Livermore National Laboratory. This work was performed for the National Atmospheric and Space Administration White Sands Missile Test Range, as reported in 1999. Laboratory experiments were performed to determine rate constants for thermal oxidation destruction of NDMA in buffered solutions simulating groundwater. Researchers then extrapolated and calculated the NDMA destruction half-life at the in situ temperatures likely to be present at the White Sands Missile Range Site (Leif, et al 1999).

The study concluded that hydrous pyrolysis oxidation was not a feasible remediation method for NDMA at the White Sands Missile Test Range. Even if temperatures of 125 degrees Celsius (°C) could be maintained underground by pressure or steam flood, the NDMA destruction half-life would be extremely slow, approaching 2,000 days (Leif, et al 1999).

2.1.4 Biodegradation

Biodegradation of NDMA by microorganisms is a technology currently in the research and development stages. Studies to determine the conditions, mechanisms, and organisms involved in biodegradation are oriented toward developing either ex situ batch process bio-reactors or in situ systems capable of destroying NDMA contaminants in groundwater. Certain species of *Pseudomonas* bacteria that oxidize methane, propane, or toluene compounds have been reported to also oxidize NDMA (Hatzinger, 2004).

Contaminant concentration thresholds pose a difficult problem for biodegradation of NDMA in groundwater. At low part-per-trillion, risk-based remediation levels, not enough contaminant is present to sustain bacterial activity and the organisms die off. One approach being investigated sustains the bacteria on a more abundant contaminant medium, like propane or toluene. This enables the bacteria to more completely oxidize low concentrations of NDMA as a co-contaminant (Hatzinger, 2004). Continued progress in understanding the biodegradation of NDMA and cultivating the conditions and cultures necessary to achieve the end results is expected. Biodegradation has not, to date, been pilot-tested at a field site where groundwater is contaminated with NDMA.

A bench-scale bioremediation study conducted with PJKS alluvial aquifer material and groundwater is presented in Section 2.2.1 of this report. The study investigated the biodegradation of NDMA and TCE by stimulating either naturally occurring or exogenous bacteria.

2.1.5 Catalytic Hydrogenation

Independent laboratory studies conducted prior to 2000 indicated that NDMA in groundwater could be ultimately decomposed to dimethylamine and ammonia by catalytic hydrogenation with nickel as the catalyst when plated on granular iron or alloyed with aluminum. The studies using granular iron plated with nickel were conducted at the University of Waterloo, Ontario, Canada, (Odziemkowski, et al, 2000) and the aluminum-nickel alloy studies were reported by the Johnson Space Center, White Sands Missile Range (Greene, et al, 2000).

In both laboratory studies, the introduction of excess hydrogen into the groundwater, through the dissolution of nickel-doped iron or the aluminum-nickel alloy, facilitated a catalytic electro-chemical reaction breaking the nitrogen-to-nitrogen bond in the NDMA, similar to degradation of NDMA by UV irradiation. Although catalytic hydrogenation for the destruction of NDMA was reported as a promising remedial technique, the possibility that NDMA could re-form in treated solutions was not addressed.

A nickel catalyst NDMA treatability study, which included bench-scale and field demonstration components, was conducted using PJKS groundwater. The bench-scale and field demonstration results are presented in Sections 2.2 and 3.0, respectively.

2.1.6 Permeable Reactive Barrier

A permeable reactive barrier (PRB) consists of a wall of reactive material that has been installed in the path of a flowing, contaminated, groundwater plume. Contaminants are treated as the groundwater penetrates the wall, which is designed to be more permeable than the surrounding aquifer material. This allows the contaminants to be treated as the groundwater readily flows through the wall without significantly altering groundwater hydrogeology (Interstate Technology & Regulatory Council [ITRC], 2005). The PRB contains materials that target specific contaminants and chemically and/or biologically degrades them. Optimally, after passing through the PRB, the groundwater contaminants will become less toxic, more readily biodegradable, or otherwise removed from the plume.

Over the past decade, the use of iron-based PRBs has evolved from innovative to accepted standard practice for the containment and treatment of a variety of groundwater contaminants. PRBs have been particularly successful when used to treat chlorinated compounds. Bench-scale studies using nanoscale zero-valent iron (ZVI) PRBs have successfully degraded NDMA. However, the literature search that was conducted for this report indicated no cases where NDMA had been successfully treated by a field-tested ZVI PRB system. Based on the successful decade-long history of chlorinated solvent treatment by iron-based systems, alternative non-iron-based reactive materials are now being researched and deployed in the United States and abroad, and reactive material that is capable of treating NDMA in a field-site PRB may be discovered (ITRC, 2005). One such potential material, zeolite, is discussed in Section 2.1.7.

2.1.7 Zeolites

Zeolites are naturally occurring clays, hydrated aluminosilicates, having cage-like structures, high surface areas, and high cation exchange capacities. Unlike other aluminosilicate clays, however, zeolites do not “shrink and swell,” which makes them suitable for flow-through applications. Natural zeolites will absorb most positively-charged, dissolved contaminants, but zeolites can also be “doped” with reactive metals or surfactants and absorb negatively-charged anionic and organic contaminants. Zeolites have been used to remove a variety of groundwater contaminants, including organic and explosive compounds, when used in flow-through columns, PRBs, and beds.

Laboratory research has showed positive results in removing gaseous-phase NDMA and other nitrosamines in vapor passed through zeolite scrubbers. A tailored clay that was initially developed by Planteco Environmental Consultants, LLC as a sorbent for perchlorate has been found to adsorb NDMA from water (ITRC, 2005). Given these laboratory successes, it is likely that NDMA could be removed from groundwater using an engineered zeolite PRB or bed at a field site where such a construction might be appropriate.

The literature search that was conducted for this report found no cases where zeolites were used to specifically remove NDMA from groundwater. Research into the application of zeolite technology for NDMA removal from groundwater remains to be done.

2.2 PJKS-SPECIFIC NDMA BENCH-SCALE STUDIES

After the initial results of the Bedrock Pilot Study, presented in Section 1.3.1, indicated ARD was not successfully treating NDMA, Shaw began evaluating two of the treatment technologies (biodegradation and catalytic hydrogenation) presented in the previous sections. Biodegradation and catalytic hydrogenation were studied at the bench-scale level, and a nickel catalyst field demonstration study was implemented following the completion of the catalytic hydrogenation bench-scale study. The results of these studies are presented in the following sections.

The bench-scale studies were conducted at the Shaw Lawrenceville Laboratory using aquifer material and groundwater collected from PJKS sources. Work on the two studies was conducted separately as outlined in the Bioremediation Work Plan (Shaw, 2004) and the Nickel Catalyst Work Plan (Shaw, 2005c).

2.2.1 Microcosm Study – In Situ Biodegradation

During a study that was funded by the National Science Foundation (NSF), Shaw's Biotechnology Development and Applications Group (formerly Envirogen, Inc.) was able to demonstrate that in situ bioremediation of NDMA may be feasible using the addition of specific co-substrates to stimulate naturally occurring or exogenous bacteria (Envirogen, 2003). As a result of the NSF study, a bench-scale study was conducted on PJKS groundwater to evaluate the feasibility of using in situ biodegradation for NDMA and TCE treatment. Because NDMA and TCE contamination occur concurrently in PJKS groundwater and both are targets of toluene-oxidizers and propanotrophs, the joint treatment of these co-contaminants by both classes of organisms was tested (Hatzinger, 2004). The objectives of the PJKS bench-scale study consisted of the following two tasks:

- *Task 1.* Determine which, if any, bioremediation technologies are capable of degrading NDMA and TCE in PJKS saturated alluvial material and groundwater.
- *Task 2.* Determine whether the successful technology or technologies identified in Task 1 are capable of achieving the Colorado Basic Standards for Groundwater (CBSG) for NDMA [0.00069 micrograms per liter (μg/L)] and TCE (5 μg/L).

2.2.1.1 Sample Collection

On October 7 and 20, 2004, saturated alluvial aquifer material was collected, using a direct-push Geoprobe sampling technique, from the East Fork Brush Creek drainage in the vicinity of Monitoring Well I-7-M1 (alluvial formation well shown on Figure 1), an area known to be contaminated with both TCE and NDMA. Additionally, approximately 5 liters (L) of groundwater were collected from Monitoring Well I-7-M1. The samples were shipped on ice to the Shaw Lawrenceville Laboratory and stored at 4°C until the bench-scale study was initiated.

To determine the baseline concentrations of NDMA and TCE in the groundwater sample submitted to the Shaw Lawrenceville Laboratory, a duplicate sample was sent to Severn-Trent Laboratories, Inc. in Arvada, Colorado (STL-Denver) for laboratory analysis. Concentrations of NDMA and TCE in the replicate were reported at 5.1 and 530 µg/L, respectively.

2.2.1.2 Shaw Lawrenceville Laboratory Procedures – Task 1

The Shaw Lawrenceville Laboratory procedures were designed to investigate NDMA and TCE degradation within two reduction-oxidation environments: aerobic and anaerobic. Sample preparations were as follows:

- Aerobic Conditions
  - Alluvial material and groundwater were added to each reaction bottle.
  - Each reaction bottle was spiked with NDMA to bring the concentration to approximately 5,000 µg/L and spiked with 1,000 µg/L of TCE.
  - Bottles were prepared in triplicate with an aerobic headspace and were treated with one of the following:
    1. No addition (aerobic control)
    2. Mercuric chloride and sodium azide addition (killed control)
    3. Propane gas (to evaluate biostimulation under aerobic control)
    4. Liquid-phase toluene (to evaluate biostimulation under aerobic conditions)
    5. Toluene plus *Pseudomonas mendocina* KR-1, a toluene-oxidizing bacterium (to evaluate bioaugmentation under aerobic conditions; observed to degrade NDMA in laboratory studies)
    6. Propane plus *Rhodococcus ruber* ENV425, a propane-oxidizing bacterium (to evaluate bioaugmentation in aerobic conditions; observed to degrade NDMA in laboratory studies)
- Anaerobic Conditions
  - Alluvial material and groundwater were added to each reaction bottle.
  - Each reaction bottle was spiked with NDMA to bring the concentration to approximately 5,000 µg/L and spiked with 1,000 µg/L of TCE.
  - Bottles were prepared in triplicate in a glove box with a nitrogen headspace, filled to the top so there was no headspace, and treated with one of the following:
    1. No addition (anaerobic control)
    2. Mercuric chloride and sodium azide addition (killed control)
    3. Lactate (to determine whether reductive dechlorination of TCE and/or anaerobic degradation of NDMA are possible under site conditions)
    4. Benzoate (also to determine whether degradation is possible in anaerobic conditions)

The microcosms were incubated over a period of three months as described in the Bioremediation Work Plan. Samples from the microcosms were periodically collected and analyzed for NDMA and TCE concentrations to determine whether degradation was occurring.

2.2.1.3 Task 1 Results

The Task 1 results are summarized as follows and graphically presented in Figures 2 through 5. Each concentration versus time point plotted on the graphs is an average of the triplicate results.

- Aerobic Conditions
  - Little reduction in NDMA concentrations was observed in all the treatment regimens (Figure 2).
  - Significant reductions in TCE concentrations were observed in the bottles treated with toluene and *Pseudomonas mendocina* KR-1 (Figure 3). TCE concentrations in the other treatment options did not differ appreciably from the killed control samples.
- Anaerobic Conditions
  - NDMA concentrations slowly declined in the lactate- and benzoate-amended microcosms and showed no significant declines after the first month. The NDMA levels in the live (unamended) microcosm continued to decline for 60 days and then leveled off. (Figure 4).

TCE concentrations were significantly reduced in all of the anaerobic treatments (no addition, benzoate, and lactate) as compared to the killed control samples (Figure 5).

2.2.1.4 Shaw Lawrenceville Laboratory Procedures – Task 2

Because none of the Task 1 treatment options produced significant reductions of NDMA concentrations, Task 2 activities were not initiated.

2.2.1.5 In Situ Bioremediation Conclusions and Recommendations

Bioremediation of NDMA was not successful and, although TCE concentrations were reduced by orders of magnitude through aerobic and anaerobic treatments in Task 1, as discussed in Section 1.3.1, ARD has been determined to be efficient and cost-effective in reducing TCE concentrations and is the preferred in situ TCE treatment for PJKS groundwater (Shaw, 2007a).

2.2.2 Nickel Catalyst Study – Ex Situ Catalytic Hydrogenation

Groundwater contaminant research conducted in the late 1990s and early 2000s indicated that chlorinated solvents could be treated via a process called catalytic hydrodehalogenation (Lowry and Reinhard, 1999; McNab and Ruiz, 1998), and by a similar catalytic hydrogenation process, NDMA could also be treated (Odziemkowski et al., 2000). In both processes, electron transfer occurs at the surface of the catalyst in the presence of dissolved hydrogen. These catalytic reactions occur at ambient temperatures and pressures (Shaw, 2005c).

Testing of catalytic hydrogenation was conducted at the Shaw Lawrenceville Laboratory to further evaluate the use of nickel catalysts for the treatment of chlorinated ethenes and NDMA in groundwater. A commercially available nickel catalyst and dissolved hydrogen were used to treat the target contaminants. Data collected during preliminary testing showed that nickel catalysts are able to rapidly degrade aqueous mixtures of chlorinated ethenes and NDMA. Similar experiments performed using natural groundwater also showed rapid degradation of tetrachloroethene, TCE, and NDMA. Separate analyses showed that ethane is the final degradation product for the chlorinated ethenes, and ammonia and methane are the final degradation products for NDMA (Shaw, 2005c; Schaefer et al., 2007).

As a result of the Shaw Lawrenceville Laboratory's preliminary studies, a bench-scale study was conducted on PJKS groundwater to evaluate the feasibility of using an ex situ nickel catalyst system for NDMA and TCE treatment. The bench-scale study consisted of two tasks: 1) a preliminary microcosm screening test, and 2) a test using the existing bench-scale reactor.

These tests were conducted to achieve the following four objectives:

- *Objective 1.* Verify that the nickel catalyst is capable of treating the NDMA and TCE in PJKS groundwater.
- *Objective 2.* Determine whether the treatment reduces NDMA concentrations to less than 0.001 µg/L in site groundwater.
- *Objective 3.* Evaluate NDMA and TCE treatment kinetics.
- *Objective 4.* Determine catalyst longevity and capability of regenerating catalyst activity in site groundwater.

2.2.2.1 Sample Collection

During collection events on October 11 and 13, 2005, a total of approximately 120 gal of groundwater were collected in 15-gal polyethylene drums with Teflon liners and shipped to the Shaw Lawrenceville Laboratory for use in the bench-scale study. The groundwater was collected from Monitoring Wells 1-M5B and 1-M6B (Fountain Formation wells, Figure 1). TCE and NDMA concentrations from these wells have been reported at maximum values of 610 and 62 µg/L, respectively. These wells represent the maximum NDMA concentrations detected at the PJKS site and have been persistent in concentration such that they are considered to be an NDMA "source area."

2.2.2.2 Shaw Lawrenceville Laboratory Procedures – Task 1

A preliminary microcosm screening test was conducted at the Shaw Lawrenceville Laboratory to determine whether any geochemical components in PJKS groundwater could inhibit nickel catalyst treatment. Carbonate, colloidal materials, and total organic carbon are some of the components that can potentially delay or prevent the abiotic nickel catalyst reaction.

2.2.2.3 Task 1 Results

Prior to the microcosm screening test, the Shaw Lawrenceville Laboratory analyzed the PJKS groundwater for pH, anions, dissolved metals, alkalinity, hardness, and total dissolved solids. The results are summarized in Table 1. The most striking characteristic of the site groundwater, specific to the Fountain Formation, was its elevated hardness (calcium carbonate at 450 milligrams per liter [mg/L]).

Two glass serum bottles were used for the microcosm screening test. One bottle was amended with approximately 0.5 grams of nickel catalyst and hydrogen gas and the other bottle was used as a control (no amendments). The Shaw Lawrenceville Laboratory analyzed the sample for the initial concentration of NDMA and determined it to be approximately 5 µg/L. The bottles were shaken for approximately four hours and reanalyzed for NDMA. The NDMA concentration in the nickel catalyst-amended bottle was measured by the Shaw Lawrenceville Laboratory to be less than 0.05 µg/L. No NDMA losses were observed in the control bottle.

2.2.2.4 Shaw Lawrenceville Laboratory Procedures – Task 2

Because the results of Task 1 demonstrated that the nickel catalyst was successful in treating NDMA, Task 2 was initiated. It was designed to evaluate the treatment of TCE- and NDMA-contaminated groundwater in a bench-scale reactor, which is shown in Appendix A, Figure 2 of the Nickel Catalyst Work Plan.

Reactor Study 1

The first reactor study using PJKS groundwater was initiated on October 31, 2005. The groundwater flow effluent rate from the 3-L reactor was set to approximately 280 milliliters per hour (mL/hour), and the nickel catalyst loading in the reactor was 8.3 grams per liter (g/L). The reactor was operated in a batch mode such that the reactor was refilled once every 165 minutes. Additional details of the reactor configuration are provided in the Nickel Catalyst Work Plan.

Reactor Study 1 Results

Reactor Study 1 results for NDMA are summarized in Table 2. Analyses presented in Table 2 were performed by the Shaw Lawrenceville Laboratory and STL-Denver. NDMA data from samples sent to STL-Denver are reported in Table 3. The results for volatile organic compounds (VOCs) and methane/ethane/ethene are summarized in Table 4; anions and ammonia results are provided in Table 5. Data are tabulated as a function of elapsed time (in days) from the start of the batch reactor experiment. The NDMA results indicated that nickel catalyst treatment can reduce concentrations of NDMA from approximately 30 µg/L to 0.0042 µg/L, (Table 3). The inconsistency in detection limits for samples analyzed by the Shaw Lawrenceville Laboratory (Table 2) are due to the variability in the volumes used for the solid phase extraction procedure that was used to concentrate the samples prior to analysis.

The VOC analyses indicate that both TCE and cis-1,2-dichloroethene (cis-1,2-DCE) were treated in the reactor, but that the reductions in TCE were typically on the order of only 60 percent (Table 4). The absence of any measurable vinyl chloride, as well as the presence of ethene, suggests that the TCE and dichloroethene (DCE) were being completely dechlorinated. The reason for the relatively low (less than 90 percent) treatment of TCE observed in the reactor may be due to the presence of elevated calcium carbonate in the reactor, as calcium carbonate is a potential catalyst poison. Calcium carbonate and groundwater hardness are discussed in greater detail in subsequent sections.

The results for anions and ammonia (Table 5) indicate that nitrate is being reduced to form ammonia, as a near-stoichiometric quantity of ammonia-from-nitrate was generated within the reactor. Ammonia is also an expected end product of NDMA degradation via the nickel catalysts. However, the theoretical quantity of nitrate produced from NDMA degradation is less than 1 percent of the theoretical quantity of nitrate produced from nitrate degradation. Thus, these sets of data could not be used to identify NDMA end products in PJKS groundwater.

Reactor testing was terminated after approximately two weeks due to excessive scaling/precipitate formation within the reactor. This scaling hindered the mixing of the catalyst within the reactor. The scaling appeared to be calcium carbonate that likely precipitated due to the reducing nature of the nickel catalyst surfaces. Efforts were made to develop a pretreatment step to prevent the calcium carbonate precipitation. Ultimately, a commercially available and regenerable ion exchange resin was used to soften the groundwater before it entered the reactor. The results of these studies are described below.

Reactor Study 2

Reactor Study 2 was performed in a similar fashion to the initial reactor study, with the following exceptions:

- Groundwater passed through a small column containing ion exchange resin prior to entering the reactor to soften the water. Parallel testing confirmed that the resin did not absorb an appreciable quantity of NDMA.
- The effluent flow was approximately 190 mL/hr.
- The catalyst loading was 3.3 g/L. This decrease in catalyst loading was intended to facilitate observation of any catalyst deactivation that might occur during the study, despite the fact that the decreased catalyst loading might prevent attaining a treatment level for NDMA of 0.001 µg/L.
- NDMA influent concentration was approximately 25 µg/L.

Reactor Study 2 Results

Experiments were initiated on December 7, 2005, and continued through January 4, 2006. The Reactor Study 2 results are summarized in Table 6. Analyses reported in Table 6 were performed by the Shaw Lawrenceville Laboratory and STL-Denver. STL-Denver results are reported in Table 3. Data are tabulated on Table 6 as a function of elapsed time (in days) from the start of the batch reactor experiment. With two exceptions when the membrane was not cleaned before sampling, the results indicate that low levels of NDMA (less than 0.056 µg/L were maintained during the study (Table 6). The VOC results, summarized in Table 7, show that greater than 96 percent of the TCE was degraded. This improvement compared to the Reactor Study 1 results may be due to the elimination of calcium carbonate from the system.

Assuming pseudo-first order kinetics for NDMA degradation, a rate constant of approximately 0.91 liters per hour per gram-(L/hr/g) catalyst was calculated at time (t)=1 day. By t=14 days, the observed first-order rate constant decreased to 0.77 L/hr/g-catalyst; by t=28 days, the rate constant decreased to 0.70 L/hr/g-catalyst (using one-half of the method detection limit as the estimated value). These calculated values of the rate constant suggest that the rate of catalyst deactivation is initially high and then slowly decreases. This observation is consistent with similar catalyst deactivation studies presented in the literature. Measured rate constants are also consistent with the initial conceptual design basis, as a rate constant on the order of 0.2 to 0.5 L/hr/g-catalyst was anticipated.

Supplemental Batch Testing

Supplemental batch testing was performed to evaluate NDMA and TCE mass balances and end products as a result of catalyst treatment. Batch tests were performed using 10 mL of site groundwater sealed in serum bottles amended with nickel catalyst (0.1 gram) and hydrogen gas headspace. An NDMA spike was added to attain a concentration of 15,000 µg/L of NDMA. This elevated NDMA concentration would, in theory, generate ammonia concentrations that could be detected above the ammonia levels generated by the nitrate reduction. The results of this study showed that the NDMA was completely denitrified, producing quantities of ammonia that approached stoichiometric values. An identical study was performed to evaluate TCE degradation, except that the bottles were spiked with TCE such that a final TCE concentration of approximately 1 mg/L was attained. The results showed that the TCE was completely degraded, with no accumulation of chlorinated ethenes.

2.2.2.5 Bench-Scale Ex Situ Catalytic Hydrogenation Conclusions and Recommendations

The major conclusions of this study were as follows:

- NDMA was completely denitrified, generating ammonia as an end-product (Objective 1).
- Treatment of greater than 95 percent of the TCE was observed, with no formation of chlorinated daughter products (Objective 1).
- Treatment of NDMA to 0.001 μg/L using nickel catalysts is attainable (Objective 2).
- The kinetics measured in the bench-scale reactor are consistent with the preliminary design, and indicate that design of a field demonstration system to treat NDMA to 0.001 μg/L is technically feasible (Objective 3).
- Treatment of NDMA to low (less than 0.056 μg/L) levels, with two exceptions noted above, was observed during a 28-day study, with very little observed catalyst deactivation (Objectives 1 and 4).

The bench-scale study indicated that evaluation of the nickel catalyst technology in a field demonstration was warranted with the recommendation that the field trial incorporate water softening as a pretreatment step.

3.0 NDMA FIELD DEMONSTRATION

Design and construction of a scaled-up version of the bench-scale system began in January 2006. The initial construction was completed, and operation of the Field Demonstration System (System) began on April 19, 2006. The objectives of the System were as follows:

- Verify the co-treatment of NDMA and TCE using nickel catalyst and dissolved hydrogen under field conditions
- Demonstrate the sustained treatment of NDMA in PJKS groundwater
- Evaluate NDMA degradation kinetics and catalyst longevity
- Determine the effectiveness of membrane filters for retaining the catalyst
- Assess the overall system process design and performance as an intermediate pilot scale system in a field environment

3.1 SYSTEM DESIGN AND CONSTRUCTION

The System was constructed onsite within a small (7-foot by 16-foot) trailer in the vicinity of Building T-1A. Photographs of the trailer and reactor apparatus are shown in Figures 6 through 8. Figure 9 presents the schematic of the System reactor.

The reactor size was increased from 3 L in the bench-scale system to 55 gal in the field demonstration. Three external membrane filters were used to accommodate the effluent flow of 0.1 gal per minute (gpm). Groundwater collected from Monitoring Well III-2-M2 (alluvial formation well), which is downgradient of the NDMA source area (Figure 1), was transported in a truck-mounted tote to the System where it was transferred into a permanently installed tote and used as the reactor influent.

The reactor vessel was constructed using a modified, air-tight, 55-gal drum. Initially, a stainless-steel drum was used. Entry ports were added to the drum lid to allow 1) the introduction of hydrogen gas, 2) recirculation/mixing of the groundwater, and 3) addition of the nickel catalyst. Hydrogen was delivered to the reactor via 150 feet of pressurized silicon tubing that was coiled inside the reactor vessel; the coiled tubing was supported on a stainless-steel cage. Hydrogen gas was also maintained in the reactor headspace. Care was taken to prevent any intrusion of air into the reactor during system startup or operation. The system was leak-tested following fabrication and prior to startup. All reactor components were bonded and grounded.

System monitoring consisted of the following:

- Influent and effluent samples were collected and analyzed by STL-Denver for VOCs by U.S. Environmental Protection Agency (EPA) SW-846 Method 8260; NDMA by both EPA SW-846 Method 8070A and a low-level STL-Denver-proprietary NDMA method; nitrate by EPA SW-846 Method 9056; and hardness (as calcium carbonate) by EPA Method 130.2. STL-Denver analytical results are presented in Table 8.
- System pressure (across the membrane filters), flow, and temperature were measured.
- Field measurements were collected for dissolved oxygen (DO) (colorimetric), nitrate (test strips), hardness (test strips), and pH (test strips).

3.2 SYSTEM OPERATION

Reactor operation was initiated on April 19, 2006, and terminated on January 12, 2007. The reactor was operated in a semibatch mode during the workweek. The reactor was either shut down or operated in recirculation mode (with the hydrogen source turned off) during the weekends for safety reasons. The reactor was also shut down on the following dates:

- May 6 through May 17, 2006 (to replace a membrane filter)
- May 27 through October 24, 2006 (to modify the reactor design, i.e., replace the stainless-steel vessel with a polyethylene vessel, as discussed later in this section)
- December 21, 2006 through January 2, 2007 (during the holidays)

The reactor was operated according to the document, *Draft Desktop Construction/Operating Procedure, NDMA Nickel Catalyst Groundwater Pilot Study* (Shaw, 2006). The overall reaction cycle occurred in three phases: fill cycle, recirculation (or batch), and drainage. Recirculation of the groundwater-catalyst slurry and hydrogen addition occurred during each phase. The fill cycle duration was 30 minutes. During the fill cycle phase, groundwater was pumped into the reactor from the 330-gal tote installed in the System trailer. Before it entered the reactor, groundwater passed through a commercial water softener to remove calcium carbonate. Groundwater was pumped into the 55-gal reaction vessel until a fill volume of approximately 45 gal was attained.

The recirculation (or batch) phase immediately followed the fill cycle phase. The typical duration of the batch cycle was 4 hours, but this cycle time varied between 2 and 6 hours throughout the demonstration. During recirculation, the groundwater-catalyst slurry was pumped through the closed reactor system (Figure 9), bypassing the membrane filters, thereby allowing for mixing and reaction. The agitation caused by the recirculation was generally sufficient to maintain the nickel catalyst particles in suspension. The catalyst used in the field-scale reactor was identical to that used in the bench-scale study. Approximately 2 pounds of nickel catalyst were used in the field-scale reactor.

The drainage phase immediately followed the batch phase, the duration of which varied between 1.5 and 2.5 hours. During the drainage phase, reactor water passed through the membrane filters. The membrane filtration system used in this demonstration consisted of two negatively-charged and one neutrally-charged ABCOR® tubular membranes purchased from Koch Membrane Systems (Model Numbers 10-HFP-276-PVI and 10-HFM-251-PVI, respectively). The transmembrane pressure required for filtration was provided by the recirculation pump. System design allowed for simultaneous operation of all three membranes. However, typically only two of the membranes operated simultaneously while the third served as a backup.

Effluent was collected for analysis starting at approximately 60 minutes into the drainage cycle. The final volume in the reactor at the end of the drainage phase depended on the drainage time and effluent flow rate. Effluent flow during the drainage cycle typically occurred at 0.13 gpm, but this rate varied between 0.06 and 0.30 gpm due to temperature change and/or accumulation of nickel on the membranes that affected the rate of filtration. The typical reactor residence time was approximately 7 hours.

Following the drainage phase, the cycle was repeated, beginning with the fill cycle.

The reactor vessel operated at ambient pressure, although a slight hydrogen headspace pressure of up to approximately 1 pound per-square-inch gauge (psig) was maintained. The reactor also operated at ambient temperature, although heat generated from the recirculation pump caused a mild to moderate increase in fluid temperature. A heating jacket was used to prevent freezing within the reactor for times when the reactor was shut down during the weekends or holidays. A PDF of the field logbook is presented in Appendix A.

3.3 SYSTEM MODIFICATION

After approximately three weeks of operation, corrosion reactions (discussed in Section 3.5) between the nickel catalyst and the stainless-steel reactor components were observed. As a result, the reactor was shut down in late May 2006 and modified to limit contact between the wet catalyst material and the stainless steel. The stainless-steel drum was replaced with a polyethylene drum; the stainless-steel cage used to support the silicon tubing was replaced with a polyvinyl chloride frame; and the recirculation pump (which contained internal stainless-steel components) was replaced with a pump that did not have stainless-steel components that came into contact with the water. Other minor system modifications were also made during this system reconfiguration, including replacement of the negatively-charged membrane filters with neutrally-charged membranes, which performed significantly better than the negatively charged membranes, and replacement of the stainless-steel float switches with plastic float switches.

Reactor operation restarted on October 25, 2006. During the remaining period of system operation, testing focused on verifying catalyst longevity and activity with respect to NDMA treatment, evaluating chemical and structural stability of the catalyst particles, and determining the long-term effectiveness of the neutrally-charged membrane filters.

3.4 SYSTEM MAINTENANCE

During routine operation of the System, the following maintenance tasks were performed:

- *Groundwater collection*. Groundwater used for the System was collected from Monitoring Well III-2-M2 (Figure 1). Because this well was approximately 2,500 feet away from the System, which was located within a Lockheed Martin Plant safety exclusion zone, the 220-gal totes had to be filled at the well and then transported to the reactor.
- *Replacement of hydrogen gas*. The hydrogen gas cylinder was replaced when the tank pressure decreased to less than 100 psig.
- *Water softener regeneration*. Periodic (every 2 to 3 weeks) regeneration of the water softener was performed using a brine solution as specified by the manufacturer.
- *Membrane maintenance*. Prior to system shutdown for the weekends (unless the System was operating in recirculation mode during the weekend), the groundwater-nickel slurry was drained from the interior of the membranes back into the reactor vessel. This process mitigated clogging/fouling of the membrane surface. In addition, membrane cleaning was performed periodically by scouring the membrane surfaces with foam spheres provided by Koch Membrane Systems to facilitate this process. This was performed by removing the membrane filter, inserting three to four foam balls at one end, and flushing these all the way through the length of the filter with high-pressure water, repeating the process three times.
- *Nickel cleaning*. During operation, the nickel catalyst gradually began to adhere to surfaces within the reaction vessel, including the silicon tubing and interior drum walls. To re-slurry

the catalyst, the reactor interior was manually scoured with a brush for several seconds. This procedure was performed one to two times per week, and only when the reactor vessel was filled with water. The reactor headspace was hydrogen-purged before resuming operation.

During weekends and/or periods of maintenance and repair of the system, water within the system recirculated without the introduction of hydrogen. The reactor operated in this “standby mode” to maintain the suspension of the catalyst or to prevent the water in the system from freezing during the cold months. Upon resumption of operations, the reactor was started at the fill cycle and allowed to run through the three phases of filling, recirculating (batch), and drainage. The System then went through an entire second cycle from which effluent samples were obtained during the drainage phase. Times were recorded for periods of active treatment versus solely contact time.

All effluent from the System (less sample volumes) was contained and transported to the Lockheed Martin wastewater treatment plant where it was treated and discharged. At the conclusion of the demonstration, the nickel catalyst was removed from the System and transported to a regulated landfill facility for disposal.

3.5 RESULTS

This section presents the results of the Field Demonstration in three parts as follows:

- Initial operation with the stainless-steel vessel (April and May 2006)
- Operation with the modified design using a polyethylene vessel (October 2006 through January 2007)

Effectiveness of the membrane filtration of the effluent for retaining the nickel catalyst

3.5.1 Initial Operation with Stainless-Steel Vessel (April and May 2006)

3.5.1.1 Physicochemical Evaluation

April and May 2006 analytical data collected for the reactor influent and effluent water are summarized in Tables 9 and 10, respectively. Analyses presented in these tables were performed by STL-Denver and MWH Laboratories, Monrovia, California. The tables specify which laboratory and which method, (for NDMA samples) has been used for the analyses. Sample results sent to STL-Denver are presented in Table 8. Field-measured data are listed in Table 11. The results through the first three weeks of operation, April 20 through May 5, 2006, (Table 10) showed that NDMA, TCE, and nitrate concentrations were significantly reduced within the reactor; NDMA concentrations decreased from approximately 3.7 µg/L (Table 9) to less than 0.001 µg/L (Table 10). Consistent with laboratory observations, no substantial sulfate reduction was observed in the reactor, and ammonia generation (from the reduction of the nitrate) occurred. However, concentrations of nickel (approximately 215 µg/L) were observed in the effluent. Temperature monitoring of the recirculated groundwater also showed that the process temperature typically ranged between 80 and 110 degrees Fahrenheit (°F) during reactor operation.

Decreases in nitrate and NDMA were due to the catalytic reaction with the nickel and hydrogen. Ammonia is the expected degradation product for NDMA, but the mass of ammonia generated from the NDMA was much less than the mass of ammonia generated from the nitrate. Periodic sampling of reduced gases did not identify the expected TCE degradation end products ethene or ethane (concentrations of these gases were at, or near, the analytical detection limit of 1 µg/L), as volatilization losses of these gases to the reactor headspace likely inhibited the ability to close the mass balance. A PDF of a table of the NDMA Cycle Schedule April 2006 – May 2006 is presented in Appendix A. *NOTE: Bench-scale testing confirmed that ethene and/or ethane are the degradation end products of TCE treatment using nickel catalysts.*

3.5.1.2 Evaluation of NDMA Degradation Kinetics and Catalyst Longevity

For operation in semibatch mode, first-order rate constants were calculated by employing a standard finite difference numerical solution to the following mass balance differential equations:

$$\frac{dM}{dt} = Q_i C_i - kC\left(\frac{V + (V - Q_e\tau)}{2}\right) \qquad \text{fill phase} \qquad \text{Eq. 1}$$

$$\frac{dM}{dt} = -kCV \qquad \text{batch phase} \qquad \text{Eq. 2}$$

$$\frac{dM}{dt} = -Q_e C_i - kC(V - Q_e t) \qquad \text{drain phase} \qquad \text{Eq. 3}$$

where M is the mass of the target contaminant (mg), t is the elapsed time *within each phase* (sec), τ is the drain time (sec), C is the contaminant concentration at cycle time t within the reactor (mg/L), C_i is the influent contaminant concentration (mg/L), V is the average reactor liquid volume (L), k is the first-order degradation rate constant (sec^{-1}), and Q_i and Q_e are the influent and effluent volumetric flow rates, respectively (L/sec).

NDMA samples were collected for analysis at approximately 60 minutes into the drainage phase.

To normalize the measured rate constants based on the nickel catalyst loading to the reactor, and to facilitate comparison of the measured rate constants to rate constants obtained in the laboratory testing, a specific surface area-based rate constant for the nickel catalyst was calculated as follows:

$$k^* = \frac{k}{\rho} \qquad \text{Eq. 4}$$

where k^* is the specific rate constant for the nickel catalyst ($(L/(sec\text{-}m^2))^{-1}$), and ρ is the total catalyst loading (m^2/L). For simplicity, in reactor experiments where small variations (less than, or equal to, 30 percent) in the reactor liquid volume occurred, an average reactor liquid volume was used to calculate the catalyst loading.

Applying Equations 1 through 4, NDMA and TCE reaction kinetics through the first two weeks of operation were estimated. The results indicated that first-order NDMA and TCE degradation rate constants of approximately 4×10^{-4} sec^{-1} and 1×10^{-4} sec^{-1}, respectively, were attained. For effluent samples below the analytical detection limit, one-half of the detection limit was used to calculate the rate constant. The corresponding specific rate constants for NDMA and TCE were 5×10^{-7} $L(sec\text{-}m^2)^{-1}$ and 1×10^{-7} $L(sec\text{-}m^2)^{-1}$, respectively. These rate constants are approximately within a factor of 2 and consistent with those observed in the laboratory testing.

Trace (less than 5 µg/L) levels of toluene were measured in the reactor influent, but toluene was detected in the reactor effluent at concentrations ranging from 1,300 to 2,100 µg/L. The reason for this increase in toluene concentration between the influent and effluent is unclear, as toluene is not an expected daughter product of any potential catalytic reaction with groundwater constituents, nor was toluene generation observed in any of the laboratory batch or reactor studies. A definitive source of the toluene was not identified.

Beginning on May 18, 2006, NDMA treatment efficiency began to rapidly decline. By May 24, 2006, the calculated first-order NDMA degradation rate constant had decreased by fifty-fold. The decrease in apparent NDMA degradation kinetics was accompanied by elevated nitrate concentrations in the effluent, increased effluent DO levels, and increases in effluent nickel concentrations. These data indicate that nickel catalyst deactivation was occurring.

After shutting down the reactor on May 24, 2006, the catalyst slurry inside the reactor was examined. The nickel catalyst showed visible signs of corrosion, including a substantial deterioration of the catalyst particle structure, and a pale-green color that was associated with both the particles themselves and with the groundwater within the reactor. These appearances were consistent with laboratory observations of the catalyst and groundwater under corrosive (low pH) conditions. Elevated dissolved nickel concentrations were also consistent with this process, as substantial Ni^{2+} species were likely present in the groundwater due to the corrosion.

The relatively rapid corrosion of the nickel particles in the field-scale reactor was unexpected, as laboratory testing showed no substantial nickel corrosion or loss of activity through four weeks. Further consideration of the field-scale reactor vessel led to the hypothesis that a Galvanic corrosion was occurring between the stainless-steel drum and the nickel particles, with the drum serving as the inert metal species and the nickel catalyst serving as the corroded metal. The laboratory reactor vessel was made from glass, so Galvanic corrosion between the nickel and the reactor vessel did not occur in the bench-scale studies.

Based on these observations and conclusions, the reactor remained shut down as the stainless-steel vessel (as well as several other stainless-steel internal components) were replaced with polyethylene to inhibit Galvanic corrosion of the catalyst.

3.5.2 Operation with Modified Design Using Polyethylene Vessel (October 2006 through January 2007)

3.5.2.1 Physicochemical Evaluation

After modifying the reactor design to limit contact between stainless-steel components and the wetted nickel, fresh catalyst was added to the System and the reactor was restarted on October 25, 2006. The analytical data collected for the reactor influent and effluent water in the modified reactor between October 2006 to January 2007 are summarized in Tables 12 and 13, respectively. All STL-Denver analytical data are presented on Table 8.

The results of reactor operation from October 2006 through January 2007 indicate that sustained treatment of NDMA to lower concentrations (µg/L) was attained and that rapid deactivation of the catalyst (analogous to what occurred during operation in May 2006) did *not* occur. Thus, the enhanced corrosion of the nickel was mitigated by replacing the stainless-steel reactor components that came into contact with water. A PDF of a table of the NDMA Cycle Schedule October 2006 – January 2007 is presented in Appendix A.

3.5.2.2 Evaluation of NDMA Degradation Kinetics and Catalyst Longevity

The calculated first-order NDMA degradation rate constants were approximately 3×10^{-4} sec^{-1}, with a corresponding specific rate constant of approximately 9×10^{-6} $L(sec\text{-}m^2)^{-1}$. These rate constants are approximately within a factor of 2 and consistent with those observed in the bench-scale testing and during initial reactor operation in April and May 2006. No decreasing trend in NDMA degradation kinetics was observed throughout the duration of the study.

Slightly elevated NDMA concentrations were observed at the final sampling event conducted on January 11, 2007. The calculated NDMA degradation rate constant on this date was 1×10^{-4} sec^{-1}. However, unlike the data shown in Tables 10 and 11, this elevated NDMA detection in the effluent was not accompanied by increases in effluent nitrate and DO concentrations, as DO and nitrate levels remained nondetections through January 12, 2007. Thus, it is unlikely that the catalyst was either deactivated or rapidly becoming deactivated. A more likely explanation for this elevated NDMA concentration is that catalyst mass had (partially) fallen out of solution. The nickel catalysts had not been cleaned/scraped from the sides of the reactor for eight days prior to the January sampling event; this procedure was typically performed 24 to 48 hours prior to NDMA sampling. Thus, the mass of catalyst in solution on January 11, 2007, was likely less than that during previous sampling events, thereby resulting in the observed decrease in activity.

Unfortunately, due to severe weather conditions, additional NDMA sampling was not performed. Visual inspection of the catalyst after termination of the field demonstration suggested that compared with the appearance of the catalyst and catalyst-groundwater slurry in May 2006, substantial catalyst corrosion had not occurred. No green color to the catalyst or groundwater was apparent, and the catalyst particles had generally retained their physical structure.

The results also indicated that TCE, nitrate, and DO[1] were degraded within the reactor, and that the TCE degradation kinetics observed in the polyethylene vessel were similar to those observed in the stainless-steel vessel.

Nickel (primarily dissolved) was also observed in the effluent. This nickel may be the result of slow corrosion of the catalyst, passage of fine catalyst particles (or fragments) through the filters, or a combination of both. However, elevated nickel concentrations of approximately 1,000 µg/L (the CBSG is 100 µg/L as defined by *Table 1 Domestic Water Supply – Human Health*

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[1] DO levels in the influent were not routinely measured, but appreciable levels of DO in the influent were likely based on historical DO readings in site groundwater. One DO measurement of the influent water in the tote showed a DO concentration of 5.5 mg/L.

Standards) were measured in the reactor effluent during preliminary testing of the modified reactor (July 2006 – data not shown), which occurred after cleaning the reactor system and replacing the stainless-steel vessel with the polyethylene vessel, but prior to adding fresh catalyst to the System. Thus, removing the dissolved/corroded nickel from the reactor system was problematic, and may have been the cause of the nickel that was observed in the effluent during system operation between October 2006 and January 2007.

Elevated toluene concentrations also remained in the effluent, although a clear trend of decreasing concentrations from April through November 2006 (Tables 10 and 13) was observed. This suggests that the presumed source (e.g., adhesive) of the toluene within the reactor was dissipating.

3.5.3 Effectiveness of Membrane Filters for Retaining Nickel Catalyst

As discussed in Sections 3.1 and 3.2 (System Design and Operation), initial operation of the reactor in April and May 2006 indicated that the neutrally-charged membrane filter performed substantially better than the negatively-charged membrane filters.

Reactor operation beginning in October 2006 employed the use of three neutrally-charged membrane filters. Initially, only the first membrane filter was used. After approximately three weeks of operation, the first filter was bypassed and Filters 2 and 3 were used. Membrane performance showed decreasing filtrate flow with time. However, periodic (i.e., one to two weeks) cleaning using the sponge balls was able to regenerate the filters, suggesting that the mechanisms for filter decline was likely due to accumulation of catalyst particles on the surface of the membrane. Improvements in filtrate flow after cleaning ranged from 27 to 100 percent.

Evaluation of the membrane filters with respect to the filterability of the catalyst-groundwater slurry was performed by calculating the filtrate flux, defined as:

$$F = \frac{Q_m}{a} \qquad \text{Eq. 5}$$

where F is the flux (gal/square foot [ft^2]/day), Q_m is the flow rate across the membrane (gal/day), and a is the membrane area. Using the second membrane filter as a basis, the average sustainable flow rate is 6 gal/hr (144 gal/day); the membrane area of each membrane filter is 2.2 ft^2. Thus, the flux across the membrane is 65 gal/ft^2/day. This flux was attained with an average membrane pressure of approximately 20 psig and a temperature of 90°F[2].

3.6 CONCLUSIONS FROM FIELD DEMONSTRATION

The specific objectives of the field demonstration were as follows:

- Verify the co-treatment of NDMA and TCE using nickel catalyst and dissolved hydrogen under field conditions,
- Demonstrate the sustained treatment of NDMA in PJKS groundwater
- Evaluate NDMA degradation kinetics and catalyst longevity

[2] Combined effluent and flow-rate readings indicate that a 10°F decrease or increase in temperature resulted in approximately a 10-percent decrease or increase in flow, respectively.

- Determine the effectiveness of membrane filters for retaining the catalyst
- Assess the overall system process design and performance as an intermediate pilot-scale system in a field environment

The nickel catalyst Field Demonstration System attained some of the overall objectives of the project. Specific findings of the field demonstration include the following:

- The nickel catalyst proved effective in treating commingled NDMA and TCE in groundwater under field conditions.
- Treatment of NDMA to concentrations below 0.7 µg/L was attained and maintained for approximately 11 weeks (October 2006 through January 2007). During this period, active treatment was conducted for 46 days and the nickel catalyst was in contact with PJKS groundwater for a total of 77 days. Approximately 2,100 gal of water were treated during this period.

> *NOTE: The CDPHE Hazardous Waste Corrective Action Unit has identified the CBSG standard for NDMA (0.00069 µg/L) as the applicable or relative and appropriate requirement (ARAR) for PJKS. However, it is not currently enforced because laboratory analytical methods are limited to detection limits that are greater than this numeric level. As stated in CDPHE Regulation No. 41, The Basic Standards for Groundwater (CDPHE, 2005), "whenever the practical quantitation limit or PQL for a pollutant is higher (less stringent) than a standard listed … the PQL shall be used in regulation specific activities." Currently, the PQL for the approved analytical method for NDMA is 0.7 µg/L and is being used as the CBSG value for NDMA results at PJKS.*
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> *The CDPHE Water Quality Control Division has issued a Draft PQL Guidance Document (August 2006) that lists the "Lowest Water Quality Standard for NDMA (0.00069 µg/L). Similar to CDPHE Regulation No. 41, the guidance acknowledges the absence of a laboratory analytical method capable of a detecting this numeric level. In the absence of a current laboratory analytical method, the guidance establishes a "PQL-Robust" numeric value to be used in regulation specific activities. The PQL for the approved analytical method for NDMA is 50 µg/L and contradicts the CBSG PQL used in conjunction with Regulation No. 41.*
>
> *On September 25, 2007, the CDPHE Water Quality Control Division, Industrial Permits Unit issued a letter to Lockheed Martin Space Systems Company and identified the PQL for NDMA is 0.05 µg/L. This numeric value is associated with Lockheed Martin's permitting requirements (permit number CO-0001511) under the CDPHE National Pollution Discharge Elimination System program resulting in a site-specific standard.*
>
> *Using the ARAR approach required under CERCLA, there are currently three different numeric values that are potentially applicable to the restoration activities being performed by the Air Force at the former Air Force PJKS Plant. Resolution of these contradictory numeric values for NDMA by CDPHE will be*

necessary to complete the CERCLA process including the feasibility study, proposed plan, and record of decision.

- NDMA degradation kinetics observed in the Field Demonstration System are consistent with those observed in the laboratory bench-scale system.
- No measurable loss of catalyst activity was observed during reactor operation from October 2006 to January 2007. Thus, sustained catalyst activity for approximately a three-month period was demonstrated.
- Neutrally-charged membrane filters were effective for retaining the undissolved nickel catalyst and maintaining filtrate flow. However, regular maintenance was required to keep the filters clear of catalyst material. The filtration system is affected by corrosion of the nickel catalyst as indicated by the clogging of the filters. In a larger scale system, increased filter surface area would be required for greater throughput. Greater expenditures for maintenance of the filters must be considered compared to alternative treatment methods.
- The presence of dissolved nickel in the effluent, as observed during the demonstration, is problematic. The concentration of dissolved nickel substantially exceeded the CBSG value of 100 µg/L as defined by Table 1 Domestic Water Supply – Human Health Standards. The persistence of nickel in the reactor effluent (approximately 400 µg/L) during operation from October 2006 to January 2007 is likely the result of the corrosion that occurred in April and May 2006; however, the extent of any additional corrosion/passage of the re-amended nickel catalyst through the membranes during the last three months of operation could not be quantified.

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TABLES

Table 1
PJKS Fountain Formation
Groundwater Geochemistry

Parameter	**Units**	**Result**
pH	SU	7.3
Chloride	mg/L	613
Sulfate	mg/L	78.8
Phosphate	mg/L	<0.1
Nitrate	mg/L	9.9
Nitrite	mg/L	<0.1
Total Iron	µg/L	<27
Total Manganese	µg/L	3.5J
Alkalinity	mg/L	209
Hardness	mg/L	450
Total Dissolved Solids	mg/L	1,310

Notes:
All analyses were performed by the Shaw Lawrenceville Laboratory

J = estimated value
µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
SU = standard units
<x.x = less than reporting limit

Table 2
Reactor Study 1 Results
NDMA Influent and Effluent

Days(1)	**Laboratory**		**NDMA (μg/L)**
1	Shaw	Influent	NA
		Effluent	<0.1
2	Shaw	Influent	NA
		Effluent	<0.098
3	Shaw	Influent	17
		Effluent	<0.065
3	STL-Denver	Influent	37
		Effluent	0.0005J
7	Shaw	Influent	21
		Effluent	<0.102
10	STL-Denver	Influent	35
		Effluent	0.25(2)
14	Shaw	Influent	12
		Effluent	<0.084

Notes:
NDMA analyses were performed at either STL-Denver laboratories or at the Shaw Lawrenceville Laboratory
(1) Elapsed time (in days) since start of reactor operation (October 31, 2005)
(2) Reactor not sampled in batch mode after a 165-minute residence time, but rather sampled in a continuous-stirred tank reactor

J = estimated value
μg/L = microgram(s) per liter
NA = not analyzed
NDMA = *n* -nitrosodimethylamine
<x.x = less than reporting limit

Table 3
Summary of Bench-Scale Nickel Catalyst Analytical Data

Location Code		NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF
Sample Number		NCTS0001	NCTS0002	NCTS0003	NCTS0004	NCTS0005	NCTS0007	NCTS0006	NCTS0008	NCTS0009	NCTS0010	NCTS0011
Sample Date		3-Nov-05	3-Nov-05	10-Nov-05	10-Nov-05	16-Nov-05	16-Nov-05	16-Nov-05	17-Nov-05	17-Nov-05	30-Nov-05	30-Nov-05
Sample Purpose		REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG
Parameter	Units											
Semivolatiles												
n-Nitrosodimethylamine	µg/L	0.00054 J	37	0.25	35	6.8	33	54 R	22 B	49 R	37	35

Location Code		NCTS-EFF	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF
Sample Number		NCTS0012	NCTS0013	NCTS0014	NCTS0015	NCTS0016	NCTS0017	NCTS0018	NCTS0019	NCTS0020
Sample Date		8-Dec-05	8-Dec-05	8-Dec-05	15-Dec-05	15-Dec-05	21-Dec-05	21-Dec-05	28-Dec-05	28-Dec-05
Sample Purpose		REG	REG	REG	REG	REG	REG	REG	REG	REG
Parameter	Units									
Semivolatiles										
n-Nitrosodimethylamine	µg/L	0.0042	19	25	1.5	26	0.013	25	23	23

Notes:
All analyses were performed by STL-Denver

B = blank contamination
J = estimated value
µg/L = microgram(s) per liter
R = rejected data

Table 4
Reactor Study 1 Results
VOC and Gasses Influent and Effluent

Days[(1)]	Location	TCE (μg/L)	DCE (μg/L)	Methane (mg/L)	Ethane (mg/L)	Ethene (mg/L)
3	Influent	23	<5	1.3 J	<2	<2
	Effluent	18	<5	1.5 J	5.8	<2
8	Influent	350	12	NA	NA	NA
	Effluent	62	<5	NA	NA	NA
9	Influent	410	15	NA	NA	NA
	Effluent	78	<5	NA	NA	NA
10	Influent	NA	NA	11.1	<2	<2
	Effluent	NA	NA	11.5	<2	16.4
11	Influent	210	7 J	NA	NA	NA
	Effluent	76	<10	NA	NA	NA

Notes:
All analyses were performed by the Shaw Lawrenceville Laboratory
(1) Elapsed time (in days) since start of reactor operation (October 31, 2005)

DCE = dichloroethene
J = estimated value
μg/L = microgram(s) per liter
mg/L = milligram(s) per liter
NA = not analyzed
TCE = trichloroethene
<x.x = less than reporting limit

Table 5
Reactor Study 1 Results
Ammonia and Anions Influent and Effluent

Days[(1)]	Location	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)
4	Influent	600	72	9.57	<0.1	0.13
	Effluent	590	69	<0.1	<0.1	11.2
10	Influent	370	77	6.46	<0.1	0.14
	Effluent	360	83	0.6	<0.1	4.4

Notes:
All analyses were performed by the Shaw Lawrenceville Laboratory
(1) Elapsed time (in days) since start of reactor operation (October 31, 2005)

mg/L = milligram(s) per liter
<x.x = less than reporting limit

Table 6
Reactor Study 2 Results
NDMA Influent and Effluent

Days[1]	Laboratory	Sample Location	NDMA (μg/L)
1	STL-Denver	Influent	25
		Effluent	0.0042
8	STL-Denver	Influent	26
		Effluent	1.5[2]
13	Shaw	Influent	NA
		Effluent	<0.031
14	STL-Denver	Influent	25
		Effluent	0.013
21	STL-Denver	Influent	23
		Effluent	23[2]
28	Shaw	Influent	NA
		Effluent	<0.056

Notes:
NDMA analyses were performed at either STL-Denver laboratories or at the Shaw Lawrenceville Laboratory
(1) Elapsed time (in days) since start of reactor operation (December 7, 2005)
(2) Membrane not properly scoured prior to sampling, as nickel catalyst was adhering to the membrane filter and was not present in solution

μg/L = microgram(s) per liter
NDMA = *n*-nitrosodimethylamine
NA = not analyzed
<x.x = less than reporting limit

Table 7
Reactor Study 2 Results
VOC Influent and Effluent

Days[1]	Location	TCE (μg/L)	DCE (μg/L)
8	Influent	320	12J
	Effluent	12	<5

Notes:
All analyses were performed by the Shaw Lawrenceville Laboratory
(1) Elapsed time (in days) since start of reactor operation (December 7, 2005)

DCE = dichloroethene
J = estimated value
μg/L = microgram(s) per liter
TCE = trichloroethene
<x.x = less than reporting limit

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

Location Code		NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-INF
Sample Number		HORSE TROUGH WATER	SS TOTE	CLEAN WATER CYCLE	EFF4001	EFF4002	EFF4031	INF4001	INF4031	EFF4004	EFF4006	INF4002
Sample Date		29-Mar-06	5-Apr-06	19-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	24-Apr-06	24-Apr-06	24-Apr-06
Sample Purpose		REG	REG	REG	REG	REG	FD	REG	FD	REG	REG	REG
Parameter	Units											
Ammonia												
Nitrogen, ammonia (as n)	mg/L		0.1 U		3.1			0.027 F				
Common Ions												
Bromide	mg/L											
Chloride	mg/L	21	99		85	96		95		98	98	97
Nitrate	mg/L	0.18 F	4.8		1 U	1 U		4.6		1 U	1 U	4.7
Nitrite	mg/L	1 U	0 U		1 U	1 U		1 U		1 U	1 U	1 U
Sulfate	mg/L	54	41		49	47		39		43	42	42
Dissolved Gases												
Ethane	µg/L				0.6 F		0.64 F	5 U			1.3 F	
Ethylene	µg/L				5 U		5 U	5 U			5 U	
Methane	µg/L				0.25 F		0.26 F	5 U			0.27 F	
General Chemistry												
Hardness (as $CaCO_3$)	mg/L		260		3.9 F			260	250			
Metals												
Aluminum	mg/L											
Arsenic	mg/L	0.03 U	0.03 U									
Barium	mg/L	0.045 F	0.36									
Cadmium	mg/L	0.005 U	0.005 U									
Calcium	mg/L	31	74									
Chromium, Total	mg/L	0.01 U	0.01 U									
Iron	mg/L	0.063 F	0.083 F									
Lead	mg/L	0.025 U	0.025 U									
Magnesium	mg/L	7.3	20									
Manganese	mg/L	0.0041 F	0.0061 F									
Nickel	mg/L	0.02 U	0.0014 F	0.11	0.043			0.02 U				
Selenium	mg/L		0.03 U									
Selenium	µg/L	30 U										
Silver	mg/L		0.01 U									
Silver	µg/L	10 U										
Semivolatiles												
n-Nitrosodimethylamine	µg/L		3.4		0.5 U		0.001 U	3.8 J P29			0.5 U	3.8
Volatiles												
1,1,1,2-Tetrachloroethane	µg/L		0.5 U		0.5 U			0.5 U			50 U	0.5 U
1,1,1-Trichloroethane	µg/L		1 U		1 U			1 U			10 U	1 U
1,1,2,2-Tetrachloroethane	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
1,1,2-Trichloroethane	µg/L		1 U		1 U			1 U			10 U	1 U
1,1-Dichloroethane	µg/L		1 U		1 U			1 U			10 U	1 U
1,1-Dichloroethene	µg/L		0.24 F		1 U			1 U			10 U	1 U
1,2-Dichloroethane	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
1,2-Dichloropropane	µg/L		1 U		1 U			1 U			10 U	1 U
2-Butanone (MEK)	µg/L		10 U		1.2 F			10 U			100 U R C.046	10 U R C.046
2-Chloroethyl Vinyl Ether	µg/L		2 U		2 U			2 U			20 U	2 U
2-Hexanone	µg/L		5 U		5 U			5 U			50 U	5 U
4-Methyl-2-Pentanone	µg/L		10 U		10 U			10 U			100 U	10 U

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

Location Code		NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-INF
Sample Number		HORSE TROUGH WATER	SS TOTE	CLEAN WATER CYCLE	EFF4001	EFF4002	EFF4031	INF4001	INF4031	EFF4004	EFF4006	INF4002
Sample Date		29-Mar-06	5-Apr-06	19-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	20-Apr-06	24-Apr-06	24-Apr-06	24-Apr-06
Sample Purpose		REG	REG	REG	REG	REG	FD	REG	FD	REG	REG	REG
Parameter	Units											
Volatiles cont.												
Acetone	µg/L		9.2 J C.033		3.4 J C.033			10 U R C.033			100 U R C.033	10 U R C.033
Benzene	µg/L		0.4 U		0.71			0.4 U			1.7 F	0.4 U
Bromodichloromethane	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
Bromoform	µg/L		1 U		1 U			1 U			10 U	1 U
Bromomethane	µg/L		3 U		3 U			3 U			30 U	3 U
Carbon Disulfide	µg/L		1 U		1 U			1 U			10 R	1 R
Carbon Tetrachloride	µg/L		1 U		1 U			1 U			10 U	1 U
Chlorobenzene	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
Chloroethane	µg/L		1 U		1 U			1 U			10 U	1 U
Chloroform	µg/L		0.56		0.3 U			0.28 F			3 U	0.28 F
Chloromethane	µg/L		1 U		1 U			1 U			10 U	1 U
cis-1,2-Dichloroethene	µg/L		8.9		1 U			4.2			10 U	3.4
cis-1,3-Dichloropropene	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
Dibromochloromethane	µg/L		0.5 U		0.5 U			0.5 U			5 U	0.5 U
Ethylbenzene	µg/L		1 U		0.91 F			1 U			10 U	1 U
Ethylene, 1,2-Dichloro-	µg/L		8.9		1 U			4.2			10 U	3.4
Freon 113	µg/L		0		0 U			0			0 U	0
Methylene Chloride	µg/L		2 U		0.28 F			2 U			20 U	2 U
Styrene	µg/L		1 U		1 U			1 U			10 U	1 U
Tetrachloroethene	µg/L		1 U		1 U			1 U			10 U	1 U
Toluene	µg/L		1 U		420 J E			1 U TB3.5			2100 JE	1 U
trans-1,2-Dichloroethene	µg/L		1 U		1 U			1 U			10 U	1 U
trans-1,3-Dichloropropene	µg/L		1 U		1 U			1 U			10 U	1 U
Trichloroethene	µg/L		710		1 U			230 J E			10 U	220 JE
Trichlorofluoromethane	µg/L		1 U		1 U			1 U			10 U	1 U
Vinyl Acetate	µg/L		2 U		2 U			2 U			20 U	2 U
Vinyl Chloride	µg/L		1 U		1 U			1 U			10 U	1 U
Xylene, o-	µg/L		1 U		1 U			1 U			10 U	1 U
Xylenes, m/p-	µg/L		2 U		2 U			2 U			20 U	2 U
Xylenes, Total	µg/L		2 U		2 U			2 U			20 U	2 U

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

Location Code		NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF
Sample Number		EFF4003	EFF4005	EFF4008	EFF4011	EFF4033	INF4003	INF4032	EFF4010	EFF4012	POST SOFTNER	EFF4013
Sample Date		26-Apr-06	28-Apr-06	2-May-06	3-May-06	3-May-06	3-May-06	3-May-06	4-May-06	5-May-06	17-May-06	18-May-06
Sample Purpose		REG	REG	REG	REG	FD	REG	FD	REG	REG	REG	REG
Parameter	Units											
Ammonia												
Nitrogen, ammonia (as n)	mg/L						0.042 F	0.1 U				
Common Ions												
Bromide	mg/L											
Chloride	mg/L	100	98		100	97	96	97				
Nitrate	mg/L	0.057 F	0.2 F		0.18 F	0.2 F	4.9	4.9				
Nitrite	mg/L	1 U	1 U		1 U	1 U	1 U	1 U				
Sulfate	mg/L	41	40 J S129		35	35	40	40				
Dissolved Gases												
Ethane	µg/L				1.2 F		5 U	5 U				
Ethylene	µg/L				5 U		5 U	5 U				
Methane	µg/L				5 U		5 U	5 U				
General Chemistry												
Hardness (as $CaCO_3$)	mg/L	3.5 F	4.2 J P									
Metals												
Aluminum	mg/L											
Arsenic	mg/L											
Barium	mg/L											
Cadmium	mg/L											
Calcium	mg/L											
Chromium, Total	mg/L											
Iron	mg/L											
Lead	mg/L											
Magnesium	mg/L											
Manganese	mg/L											
Nickel	mg/L	0.14	0.16				0.0017 F	0.0016 F				0.22
Selenium	mg/L											
Selenium	µg/L											
Silver	mg/L											
Silver	µg/L											
Semivolatiles												
n-Nitrosodimethylamine	µg/L	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3.1	3.4	0.5 U	0.5 U	4.6	0.62
Volatiles												
1,1,1,2-Tetrachloroethane	µg/L				3.3 U		1 U	1 U			0.5 U	
1,1,1-Trichloroethane	µg/L				6.7 U		2 U	2 U			1 U	
1,1,2,2-Tetrachloroethane	µg/L				3.3 U		1 U	1 U			0.5 U	
1,1,2-Trichloroethane	µg/L				6.7 U		2 U	2 U			1 U	
1,1-Dichloroethane	µg/L				6.7 U		2 U	2 U			1 U	
1,1-Dichloroethene	µg/L				6.7 U		2 U	2 U			1 U	
1,2-Dichloroethane	µg/L				3.3 U		1 U	1 U			0.5 U	
1,2-Dichloropropane	µg/L				6.7 U		2 U	2 U			1 U	
2-Butanone (MEK)	µg/L				67 U R C.045		20 U R C.045	20 U R C.045			10 U R C.037	
2-Chloroethyl Vinyl Ether	µg/L				13 U		4 U	4 U			2 U	
2-Hexanone	µg/L				33 U		10 U	10 U			5 U	
4-Methyl-2-Pentanone	µg/L				67 U		20 U	20 U			10 U	

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

Location Code		NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF
Sample Number		EFF4003	EFF4005	EFF4008	EFF4011	EFF4033	INF4003	INF4032	EFF4010	EFF4012	POST SOFTNER	EFF4013
Sample Date		26-Apr-06	28-Apr-06	2-May-06	3-May-06	3-May-06	3-May-06	3-May-06	4-May-06	5-May-06	17-May-06	18-May-06
Sample Purpose		REG	REG	REG	REG	FD	REG	FD	REG	REG	REG	REG
Parameter	Units											
Volatiles cont.												
Acetone	µg/L				67 U R C.033		20 U R C.033	20 U R C.033			10 U R C.021	
Benzene	µg/L				1.6 F		0.8 U	0.8 U			0.3 F	
Bromodichloromethane	µg/L				3.3 U		1 U	1 U			0.54	
Bromoform	µg/L				6.7 U		2 U	2 U			1 U	
Bromomethane	µg/L				20 U		6 U	6 U			3 R	
Carbon Disulfide	µg/L				6.7 R		2 R	2 R			0.26 F	
Carbon Tetrachloride	µg/L				6.7 U		2 U	2 U			1 U	
Chlorobenzene	µg/L				3.3 U		1 U	1 U			0.5 U	
Chloroethane	µg/L				6.7 U		2 U	2 U			1 U	
Chloroform	µg/L				2 U		0.46 F	0.48 F			0.88	
Chloromethane	µg/L				6.7 U		2 U	2 U			1 U	
cis-1,2-Dichloroethene	µg/L				6.7 U		7.5	7.7			6.4	
cis-1,3-Dichloropropene	µg/L				3.3 U		1 U	1 U			0.5 U	
Dibromochloromethane	µg/L				3.3 U		1 U	1 U			0.2 F	
Ethylbenzene	µg/L				6.7 U		2 U	2 U			1 U	
Ethylene, 1,2-Dichloro-	µg/L				6.7 U		7.5	7.7			6.4	
Freon 113	µg/L				0 U		0	0			0	
Methylene Chloride	µg/L				2.9 F		4 U	0.46 F			2 U	
Styrene	µg/L				6.7 U		2 U	2 U			1 U	
Tetrachloroethene	µg/L				6.7 U		2 U	2 U			1 U	
Toluene	µg/L				1300 JE		2 U	2 U			0.52 F	
trans-1,2-Dichloroethene	µg/L				6.7 U		2 U	2 U			1 U	
trans-1,3-Dichloropropene	µg/L				6.7 U		2 U	2 U			1 U	
Trichloroethene	µg/L				6.7 U		460 J E	470 J E			240	
Trichlorofluoromethane	µg/L				6.7 U		2 U	2 U			1 U	
Vinyl Acetate	µg/L				13 U		4 U	4 U			2 U	
Vinyl Chloride	µg/L				6.7 U		2 U	2 U			1 U	
Xylene, o-	µg/L				6.7 U		2 U	2 U			0.16 F	
Xylenes, m/p-	µg/L				13 U		4 U	4 U			2 U	
Xylenes, Total	µg/L				13 U		4 U	4 U			2 U	

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

Location Code		NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF
Sample Number		EFF4016	EFF CHECK	EFF SYSTEM CHECK	NI-CA FILTER A	NI-CA FILTER B	NI-CA FILTER C	EFF4017	INF4004	EFF4019	EFF4020	EFF4032
Sample Date		19-May-06	23-May-06	24-May-06	26-Jul-06	26-Jul-06	26-Jul-06	4-Oct-06	4-Oct-06	6-Oct-06	2-Nov-06	2-Nov-06
Sample Purpose		REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	FD
Parameter	Units											
Ammonia												
Nitrogen, ammonia (as n)	mg/L											
Common Ions												
Bromide	mg/L							0.18 F	0.19 F		0.31 F	0.35 F
Chloride	mg/L							250	260		1000	980
Nitrate	mg/L		2.2					2.9	3.2		2 U	2 U
Nitrite	mg/L		1 U					1 U	1 U		2 U	0.35 J S155
Sulfate	mg/L							37	38		43	44
Dissolved Gases												
Ethane	µg/L											
Ethylene	µg/L											
Methane	µg/L											
General Chemistry												
Hardness (as $CaCO_3$)	mg/L			1.9 F							280	300
Metals												
Aluminum	mg/L				0.2 UB30	0.2 UB30	0.2 UB30	0.2 U	0.2 U	0.02 F	0.2 U	0.2 U
Arsenic	mg/L				0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
Barium	mg/L				0.05 U	0.05 U	0.05 U	0.0012 F	0.49	0.05 U	0.054	0.054
Cadmium	mg/L				0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Calcium	mg/L				0.098 F	1.1 UB110	0.086 F	4.3	110	1.1	50	49
Chromium, Total	mg/L				0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Iron	mg/L				0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.028 F	0.2 U	0.2 U
Lead	mg/L				0.025 U	0.025 U	0.025 U	0.025 U	0.025 U	0.025 U	0.025 U	0.0044 F
Magnesium	mg/L				1 U	1 U	1 U	0.33 F	30	0.23 F	38	37
Manganese	mg/L				0.0025 F	0.002 F	0.01 U	0.01 U	0.016	0.01 U	0.01 U	0.01 U
Nickel	mg/L				1.3	1.1	0.15	4.8	0.02 U	2.6	3.6	3.5
Selenium	mg/L											
Selenium	µg/L				30 U	30 U	30 U	30 U	30 U	30 U	30 U	30 U
Silver	mg/L											
Silver	µg/L				10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Semivolatiles												
n-Nitrosodimethylamine	µg/L	1.6		2.2				1.7	1.8			
Volatiles												
1,1,1,2-Tetrachloroethane	µg/L							0.5 U	0.5 U		2 U	2 U
1,1,1-Trichloroethane	µg/L							1 U	1 U		4 U	4 U
1,1,2,2-Tetrachloroethane	µg/L							0.5 U	0.5 U		2 U	2 U
1,1,2-Trichloroethane	µg/L							1 U	1 U		4 U	4 U
1,1-Dichloroethane	µg/L							0.3 F	0.59 F		4 U	4 U
1,1-Dichloroethene	µg/L							1 U	1 U		4 U	4 U
1,2-Dichloroethane	µg/L							0.5 U	0.5 U		2 U	2 U
1,2-Dichloropropane	µg/L							1 U	1 U		4 U	4 U
2-Butanone (MEK)	µg/L							10 U	10 U		40 UR C.022	40 UR C.024
2-Chloroethyl Vinyl Ether	µg/L							2 U	2 U		8 U	8 U
2-Hexanone	µg/L							5 U	5 U		20 U	20 U
4-Methyl-2-Pentanone	µg/L							10 U	10 U		40 U	40 U

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

	Location Code	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF
	Sample Number	EFF4016	EFF CHECK	EFF SYSTEM CHECK	NI-CA FILTER A	NI-CA FILTER B	NI-CA FILTER C	EFF4017	INF4004	EFF4019	EFF4020	EFF4032
	Sample Date	19-May-06	23-May-06	24-May-06	26-Jul-06	26-Jul-06	26-Jul-06	4-Oct-06	4-Oct-06	6-Oct-06	2-Nov-06	2-Nov-06
	Sample Purpose	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	FD
Parameter	Units											
Volatiles cont.												
Acetone	µg/L							2.4 J C.03	3.7 J C.03		40 UR C.018	40 UR C.018
Benzene	µg/L							0.8 U	0.4 U		1.6 U	1.6 U
Bromodichloromethane	µg/L							0.44 F	0.5 U		2 U	2 U
Bromoform	µg/L							1 U	1 U		4 U	4 U
Bromomethane	µg/L							3 U	3 U		12 U	12 U
Carbon Disulfide	µg/L							1 U	1 U		4 U	4 U
Carbon Tetrachloride	µg/L							1 U	1 U		4 U	4 U
Chlorobenzene	µg/L							0.5 U	0.5 U		2 U	2 U
Chloroethane	µg/L							1 U	1 U		4 U	4 U
Chloroform	µg/L							1.3	0.4		1.2 U	1.2 U
Chloromethane	µg/L							1 U	1 U		4 U	4 U
cis-1,2-Dichloroethene	µg/L							9.6	18		4 U	4 U
cis-1,3-Dichloropropene	µg/L							0.5 U	0.5 U		2 U	2 U
Dibromochloromethane	µg/L							0.5 U	0.5 U		2 U	2 U
Ethylbenzene	µg/L							1 U	1 U		4 U	4 U
Ethylene, 1,2-Dichloro-	µg/L							9.6	18		4 U	4 U
Freon 113	µg/L							0 U	0		0 U	0 U
Methylene Chloride	µg/L							0.58 F	2 U		8 U TB2.1	8 U TB2.1
Styrene	µg/L							1 U	1 U		4 U	4 U
Tetrachloroethene	µg/L							1 U	1 U		4 U	4 U
Toluene	µg/L							3.7	1 U		1000	1000
trans-1,2-Dichloroethene	µg/L							1 U	1 U		4 U	4 U
trans-1,3-Dichloropropene	µg/L							1 U	1 U		4 U	4 U
Trichloroethene	µg/L							79 J	410 J E		4 U	4 U
Trichlorofluoromethane	µg/L							1 U	1 U		4 U	4 U
Vinyl Acetate	µg/L							2 U	2 U		8 U	8 U
Vinyl Chloride	µg/L							1 U	1 U		4 U	4 U
Xylene, o-	µg/L							1 U	1 U		4 U	4 U
Xylenes, m/p-	µg/L							2 U	2 U		8 U	8 U
Xylenes, Total	µg/L							2 U	2 U		8 U	8 U

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

	Location Code	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF
	Sample Number	INF4005	INF4020	EFF4025	EFF4030	EFF4034	EFF4035	INF4007	EFF4036	INF4008
	Sample Date	13-Nov-06	13-Nov-06	16-Nov-06	28-Nov-06	6-Dec-06	14-Dec-06	14-Dec-06	20-Dec-06	20-Dec-06
	Sample Purpose	REG	FD	REG	REG	REG	REG	REG	REG	REG
Parameter	Units									
Ammonia										
Nitrogen, ammonia (as n)	mg/L									
Common Ions										
Bromide	mg/L	0.17 F	0.17 F	0.16 F	0.19 F					
Chloride	mg/L	230	220	230	210					
Nitrate	mg/L	3.6	3.6	0.21 F	0.1 F					
Nitrite	mg/L	1 U	1 U	1 U	1 U					
Sulfate	mg/L	40	40	37	35					
Dissolved Gases										
Ethane	µg/L									
Ethylene	µg/L									
Methane	µg/L									
General Chemistry										
Hardness (as $CaCO_3$)	mg/L									
Metals										
Aluminum	mg/L	0.2 U	0.2 U	0.2 U	0.2 U					
Arsenic	mg/L	0.03 U	0.0048 F	0.03 U	0.03 U					
Barium	mg/L	0.47	0.45	0.0026 F	0.0018 F					
Cadmium	mg/L	0.005 U	0.005 U	0.005 U	0.005 U					
Calcium	mg/L	97 B	110 B	1.8 B	0.77 F					
Chromium, Total	mg/L	0.01 U	0.01 U	0.01 U	0.01 U					
Iron	mg/L	0.2 U	0.2 U	0.2 U	0.2 U					
Lead	mg/L	0.025 U	0.025 U	0.025 U	0.025 U					
Magnesium	mg/L	29	28	0.1 F	0.046 F					
Manganese	mg/L	0.01 U	0.01 U	0.01 U	0.01 U					
Nickel	mg/L	0.099	0.11	0.33	0.35	0.34	0.34		0.36	
Selenium	mg/L									
Selenium	µg/L	30 U	30 U	30 U	30 U					
Silver	mg/L									
Silver	µg/L	10 U	10 U	10 U	10 U					
Semivolatiles										
n-Nitrosodimethylamine	µg/L	2.6	3.1	0.001 U	0.001 U			2.8		3
Volatiles										
1,1,1,2-Tetrachloroethane	µg/L	1 U	1 U	0.5 U	1 U					
1,1,1-Trichloroethane	µg/L	2 U	2 U	1 U	2 U					
1,1,2,2-Tetrachloroethane	µg/L	1 U	1 U	0.5 U	1 U					
1,1,2-Trichloroethane	µg/L	2 U	2 U	1 U	2 U					
1,1-Dichloroethane	µg/L	0.62 F	0.58 F	1 U	2 U					
1,1-Dichloroethene	µg/L	2 U	2 U	1 U	2 U					
1,2-Dichloroethane	µg/L	1 U	1 U	0.5 U	1 U					
1,2-Dichloropropane	µg/L	2 U	2 U	1 U	2 U					
2-Butanone (MEK)	µg/L	20 UR C.024	20 UR C.024	10 UR C.021	20 UR C.018					
2-Chloroethyl Vinyl Ether	µg/L	4 U	4 U	2 U	4 U					
2-Hexanone	µg/L	10 U	10 U	5 U	10 U					
4-Methyl-2-Pentanone	µg/L	20 U	20 U	10 U	20 U					

Table 8
Summary of Field Demonstration Nickel Catalyst Analytical Data
Analyses Performed by STL-Denver

	Location Code	NCTS-INF	NCTS-INF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-EFF	NCTS-INF	NCTS-EFF	NCTS-INF
	Sample Number	INF4005	INF4020	EFF4025	EFF4030	EFF4034	EFF4035	INF4007	EFF4036	INF4008
	Sample Date	13-Nov-06	13-Nov-06	16-Nov-06	28-Nov-06	6-Dec-06	14-Dec-06	14-Dec-06	20-Dec-06	20-Dec-06
	Sample Purpose	REG	FD	REG	REG	REG	REG	REG	REG	REG
Parameter	Units									
Volatiles cont.										
Acetone	µg/L	20 UR C.018	20 UR C.018	10 UR C.016	20 UR C.018					
Benzene	µg/L	0.8 U	0.8 U	0.22 F	0.32 F					
Bromodichloromethane	µg/L	1 U	1 U	0.5 U	1 U					
Bromoform	µg/L	2 U	2 U	1 U	2 U					
Bromomethane	µg/L	6 U	6 U	3 U	6 U					
Carbon Disulfide	µg/L	2 U	2 U	1 U	2 U					
Carbon Tetrachloride	µg/L	2 U	2 U	1 U	2 U					
Chlorobenzene	µg/L	1 U	1 U	0.5 U	1 U					
Chloroethane	µg/L	2 U	2 U	1 U	2 U					
Chloroform	µg/L	0.55 F	0.56 F	0.3 U	0.6 U					
Chloromethane	µg/L	2 U	2 U	1 J S54	2 U					
cis-1,2-Dichloroethene	µg/L	20	20	1 U	2 U					
cis-1,3-Dichloropropene	µg/L	1 U	1 U	0.5 U	1 U					
Dibromochloromethane	µg/L	1 U	1 U	0.5 U	1 U					
Ethylbenzene	µg/L	2 U	2 U	1 U	2 U					
Ethylene, 1,2-Dichloro-	µg/L	20	19	1 U	2 U					
Freon 113	µg/L	0	0	0 U	0 U					
Methylene Chloride	µg/L	40 U B4	40 U B4	2 U B.22	0.65 F					
Styrene	µg/L	2 U	2 U	1 U	2 U					
Tetrachloroethene	µg/L	2 U	2 U	1 U	2 U					
Toluene	µg/L	2 U	2 U	510	460					
trans-1,2-Dichloroethene	µg/L	2 U	2 U	1 U	2 U					
trans-1,3-Dichloropropene	µg/L	2 U	2 U	1 U	2 U					
Trichloroethene	µg/L	550	530	0.3 F	2 U					
Trichlorofluoromethane	µg/L	2 U	2 U	1 U	2 U					
Vinyl Acetate	µg/L	4 U	4 U	2 U	4 U					
Vinyl Chloride	µg/L	2 U	2 U	1 U	2 U					
Xylene, o-	µg/L	2 U	2 U	1 U	2 U					
Xylenes, m/p-	µg/L	4 U	4 U	2 U	4 U					
Xylenes, Total	µg/L	4 U	4 U	2 U	4 U					

Table 9
Analytical Data for Reactor Influent During Operation in April and May 2006

Sample Number	Sample Date	NDMA (µg/L)	TCE (µg/L)	DCE (µg/L)	VC (µg/L)	Toluene (µg/L)	Sulfate (mg/L)	Nitrate[(1)] (mg/L)	Nitrite[(1)] (mg/L)	Ammonia (mg/L)	Nickel (total) (µg/L)	Nickel (dissolved) (µg/L)	Hardness[(2)] (mg/L)
INF4001	4/20/2006	3.8 J	230	4.2 F	<10	<1	39	4.6	<1	0.027 F	<20	1.4 F	260
INF4002	4/24/2006	3.8	220	3.4	<1	<1	42	4.7	<1	NS	NS	NS	NS
INF4003	5/3/2006	3.1	460 J	7.5	<2	<2	40	4.9	<1	0.042 F	1.7 F	<20	NS
INF4032	5/3/2006 (dup)	3.4	470 J	7.7	<2	<2	40	4.9	<1	<1	1.6 F	1.8 F	NS
Post Softener	5/17/2006[(a)]	4.6	240	6.4	<1	0.52 F	NS	NS	NS	NS	NS	NS	NS

Notes:
All analyses were performed by STL-Denver
(a) Sample collected downstream of water softener, but prior to entering reactor
(1) Nitrate, nitrite as mg/L nitrogen
(2) Hardness as calcium carbonate ($CaCO_3$)

DCE = dichloroethene
F = estimated value
J = estimated value
µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
NDMA = *n*-nitrosodimethylamine
NS = not sampled
TCE = trichloroethene
VC = vinyl chloride
<x.x = less than reporting limit

Table 10
Analytical Data for Reactor Effluent During Operation in April and May 2006

Sample Number	Sample Date	NDMA (µg/L)	TCE (µg/L)	DCE (µg/L)	VC (µg/L)	Toluene (µg/L)	Sulfate (mg/L)	Nitrate(1) (mg/L)	Nitrite(1) (mg/L)	Ammonia (mg/L)	Nickel (total) (µg/L)	Nickel (dissolved) (µg/L)	Hardness(2) (mg/L)
EFF4001(3)	4/20/2006	<0.002	<1	<1	<1	420 J	49	<1	<1	3.1	43	44	3.9 F
EFF4002(3)	4/20/2006	<0.002	NS	NS	NS	NS	47	<1	<1	NS	NS	NS	NS
EFF4006(3)	4/24/2006	<0.002	<10	<10	<10	2100 J	42	<1	NS	NS	NS	NS	NS
EFF4004(3)	4/25/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4003(3)	4/26/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	140	140	NS
EFF4007(3)	4/26/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4005(3)	4/28/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	160	160	NS
EFF4009(3)	5/1/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4008(3)	5/2/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4011(3)	5/3/2006	<0.002	<6.7	<6.7	<6.7	1300 J	35	0.18 F	<1	NS	NS	NS	NS
EFF4033(4)	5/3/2006 (dup)	<0.002	NS	NS	NS	NS	35	0.2	NS	NS	NS	NS	NS
EFF4010(4)	5/4/2006	<0.001	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4012(4)	5/5/2006	<0.001	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4013(5)	5/18/2006	0.62	NS	NS	NS	NS	NS	NS	NS	NS	220	210	NS
EFF4016(6)	5/19/2006	1.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF-Check(7)	5/23/2006	NS	NS	NS	NS	NS	NS	2.2	<1	NS	NS	NS	NS
EFF Sys-Chk(5)	5/24/2006	2.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.4

(1) Nitrate, nitrite as mg/L nitrogen
(2) Hardness as calcium carbonate ($CaCO_3$)
(3) NDMA analyses were performed by MWH Laboratories, Monrovia, California using continuous liquid liquid extraction protocol. Other analyses were performed by STL-Denver.
(4) NDMA analyses were performed by STL-Denver using their proprietary low-level method. Other analyses were performed by STL-Denver.
(5) NDMA analyses were performed by STL-Denver using EPA SW-846 Method SW8070A. Other analyses were performed by STL-Denver.
(6) NDMA analyses were performed by STL-Denver using EPA SW-846 Method SW8070A.
(7) All analyses were performed by STL-Denver.

DCE = dichloroethene
F = estimated value
J = estimated value
µg/L = microgram(s) per liter
mg/L = milligrams per liter
NDMA = *n*-nitrosodimethylamine
NS = not sampled
TCE = trichloroethene
VC = vinyl chloride
< x.x = less than reporting limit

Table 11
Reactor Effluent Field Measurements
April and May 2006

Sample Date	DO (mg/L)	Nitrate[(1)] (mg/L)	Hardness (mg/L)
4/19/2006	NS	8.0	<1
4/20/2006	<1	<0.5	<1
4/21/2006	<1	<0.5	<1
4/24/2006	<1	<0.5	<1
4/25/2006	<1	<0.5	<1
4/26/2006	<1	<0.5	<1
4/27/2006	NS	<0.5	<1
4/28/2006	NS	<0.5	<1
5/1/2006	NS	<0.5	NS
5/2/2006	NS	<0.5	NS
5/3/2006	NS	<0.5	NS
5/4/2006	NS	<0.5	NS
5/5/2006	NS	<0.5	NS
5/18/2006	NS	0.5	NS
5/19/2006	NS	2.0	NS
5/22/2006	<1	1.0	<1
5/23/2006	1.0/1.5/1.5	2.0/2.0	<1
5/24/2006	1.8	2.5	<1

Notes:
All field measurements are approximate
(1) Nitrate as mg/L nitrogen. Readings at or above 0.5 mg/L represent a clear nitrate detection on the test paper.

DO = dissolved oxygen
mg/L = milligram(s) per liter
NS = not sampled
<x.x = less than reporting limit

Table 12
Analytical Data for Reactor Influent During Operation from October 2006 to January 2007

Sample Number	Sample Date	NDMA (µg/L)	TCE (µg/L)	DCE (µg/L)	VC (µg/L)	Toluene (µg/L)	Sulfate (mg/L)	Nitrate[1] (mg/L)	Nitrite[1] (mg/L)	Ammonia (mg/L)	Nickel (total) (µg/L)	Nickel (dissolved) (µg/L)
INF4004[2]	10/4/2006	1.80	410 J	18	<1	<1	38	3.2	<1	NS	<20	<20
INF4005[2]	11/13/2006	2.60	550	20	<2	<2	40	3.6	<1	NS	100	99
INF4020[2](dup)	11/13/2006	3.10	530	20	<2	<2	40	3.6	<1	NS	100	110
INF4007[2]	12/14/2006	2.80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
INF4008[2]	12/20/2006	3.00	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
INF4009[3]	1/4/2007	2.78	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
INF4010[3]	1/11/2007	3.09	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

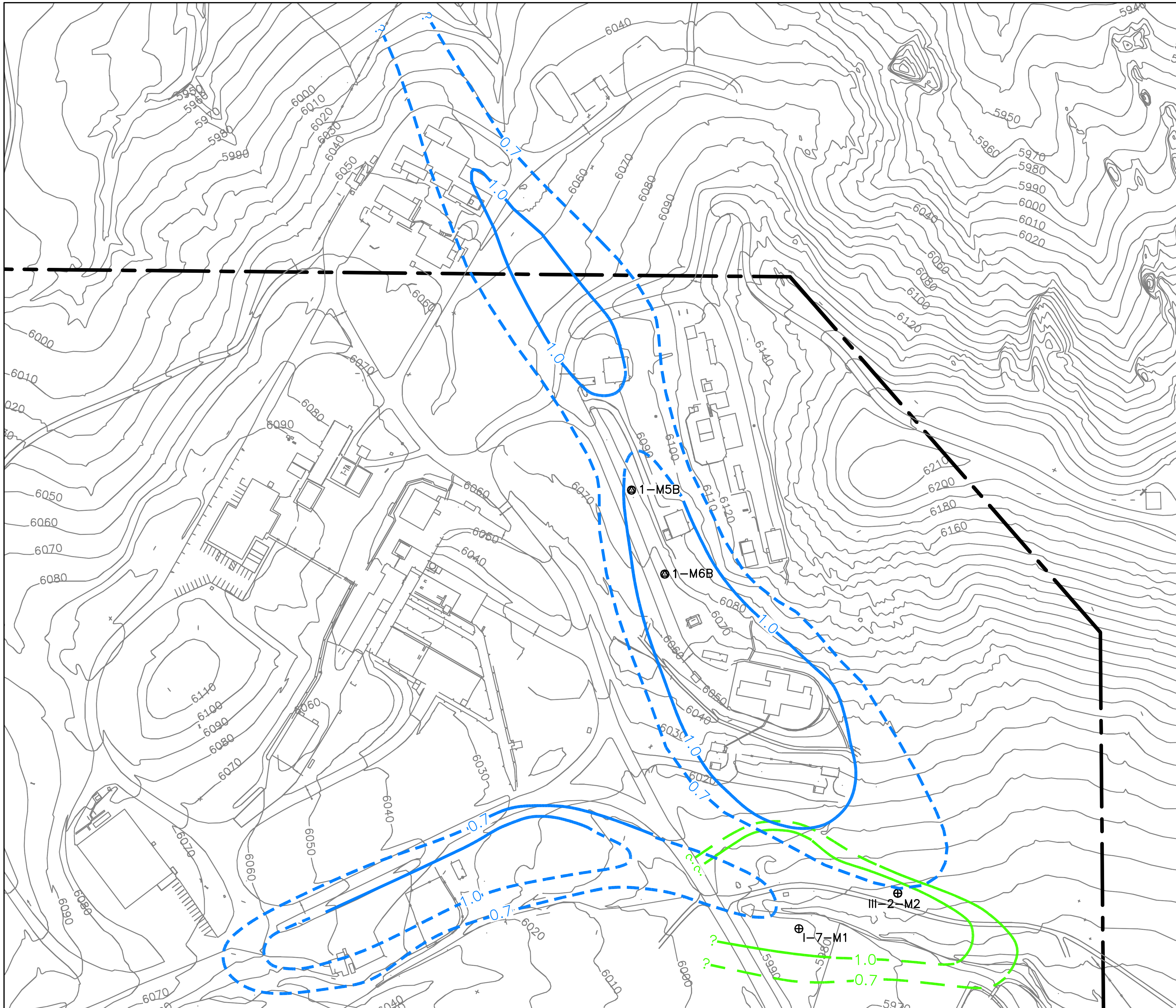
Notes:
(1) Nitrate, nitrite as mg/L nitrogen
(2) All analyses were performed by STL-Denver
(3) NDMA analyses were performed by MWH Laboratories, Monrovia, California

DCE = dichloroethene
J = estimated value
µg/L = microgram(s) per liter
mg/L = milligram(s) per liter
NDMA = *n* -nitrosodimethylamine
NS = not sampled
TCE = trichloroethene
VC = vinyl chloride
<x.x = less than reporting limit

Table 13
Analytical Data for Reactor Effluent During Operation from October 2006 to January 2007

Sample Number	Sample Date	NDMA (µg/L)	TCE (µg/L)	DCE (µg/L)	VC (µg/L)	Toluene (µg/L)	Sulfate (mg/L)	Nitrate(1) (mg/L)	Nitrite(1) (mg/L)	Ammonia (mg/L)	Nickel (total) (µg/L)	Nickel (dissolved) (µg/L)
EFF4017(2)	10/4/2006	1.7	79 J	9.6	<1	3.7	37	2.9	<1	NS	4600.0	4800.0
EFF4019(2)	10/6/2006	NS	NS	NS	NS	NS	NS	NS	NS	NS	2600.0	2600.0
EFF4021(3)	10/27/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4022(4)	10/30/2006	<0.002	<0.5	<0.5	<0.5	1240	NS	NS	NS	NS	NS	NS
EFF4023(3)	11/1/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4020(2)	11/2/2006	NS	<4	<4	<4	1000	43	<2	<2 U	NS	3600	3600
EFF4032(2)(dup)	11/2/2007	NS	<4	<4	<4	1000	44	<2	0.36F	NS	3700	3500
EFF4024(3)	11/3/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4025(3)	11/8/2006	0.0023	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4026(3)	11/10/2006	0.0058	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4027(3)	11/14/2006	0.0044	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4025(5)	11/16/2006	0.0021	0.3	<1	<1	510	37	0.21 F	<1	NS	340	330
EFF4029(4)	11/21/2006	0.0041	<1	<1	<1	349	NS	NS	NS	NS	NS	NS
EFF4030(6)	11/28/2006	0.0026	<2	<2	<2	460	35	0.1 F	<1	NS	440	350
EFF4031(3)	11/30/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EFF4034(7)	12/6/2006	0.0160	NS	NS	NS	NS	NS	NS	NS	NS	340	340
EFF4035(7)	12/14/2006	0.0020	NS	NS	NS	NS	NS	NS	NS	NS	350	340
EFF4036(7)	12/20/2006	<0.002	NS	NS	NS	NS	NS	NS	NS	NS	360	350

FIGURES



LEGEND

⊕ I-7-M1	ALLUVIAL WELLS USED DURING STUDIES
1-M6B	FOUNTAIN WELLS USED DURING STUDIES
1.0	ALLUVIAL AQUIFER NDMA PLUME CONCENTRATION CONTOUR (DASHED WHERE INFERRED) 2004 FALL CONTOUR FROM 2004 ANNUAL GROUNDWATER MONITORING REPORT, REV.0, SHAW, APRIL 20, 2005
1.0	FOUNTAIN AQUIFER NDMA PLUME CONCENTRATION CONTOUR (DASHED WHERE INFERRED) 2004 FALL CONTOUR FROM 2004 ANNUAL GROUNDWATER MONITORING REPORT, REV.0, SHAW, APRIL 20, 2005
6140	EXISTING TOPO CONTOUR INTERVAL = 10 FT.
	PJKS BOUNDARY

0 100 200

SCALE: 1" = 200'

N

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	LWA	PSM	10/05/07

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 1

BENCH-SCALE/ FIELD TRIAL GROUNDWATER COLLECTION WELLS

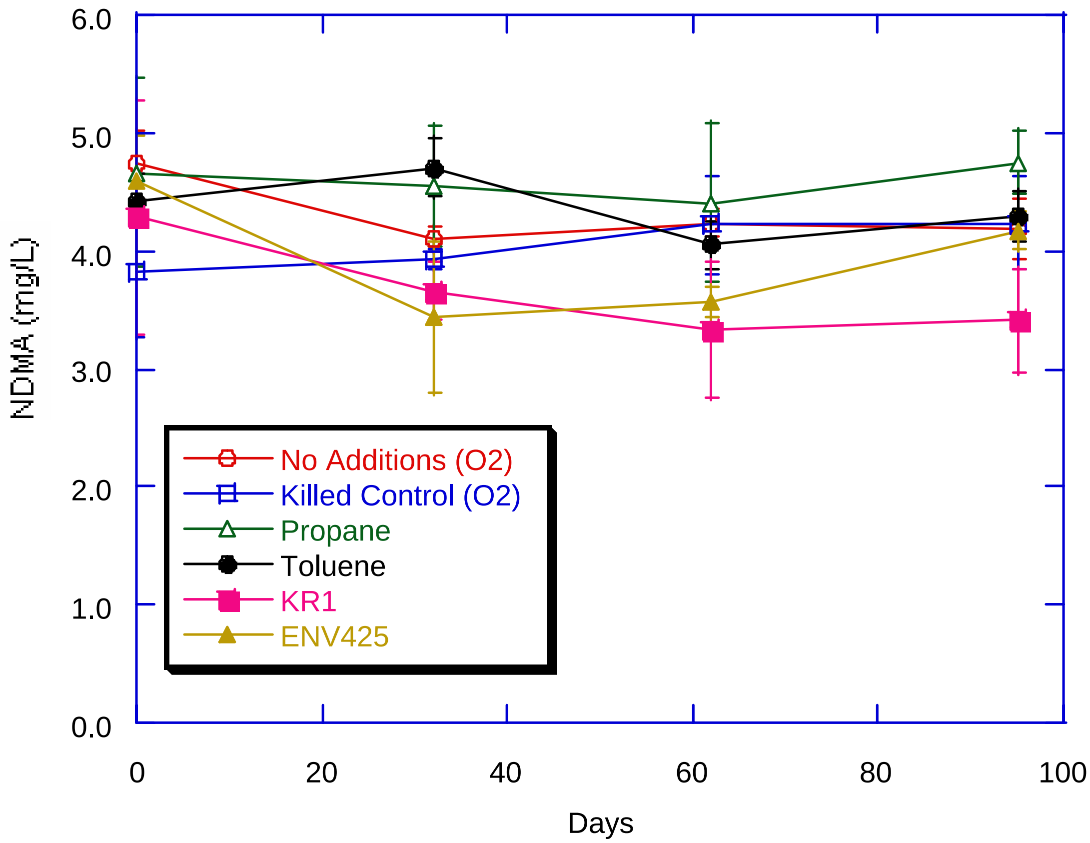
Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DSND	MEC	06/27/07	CHKD	LWA	06/28/07	121412.0400	0	121412C050
DRAWN	MEC	06/27/07	APPR	PMS	06/28/07			

MON, NOV 05, 2007 10:05 A MEC O:\PJKS\121412\C-0400\REV-0\121412C050.DWG

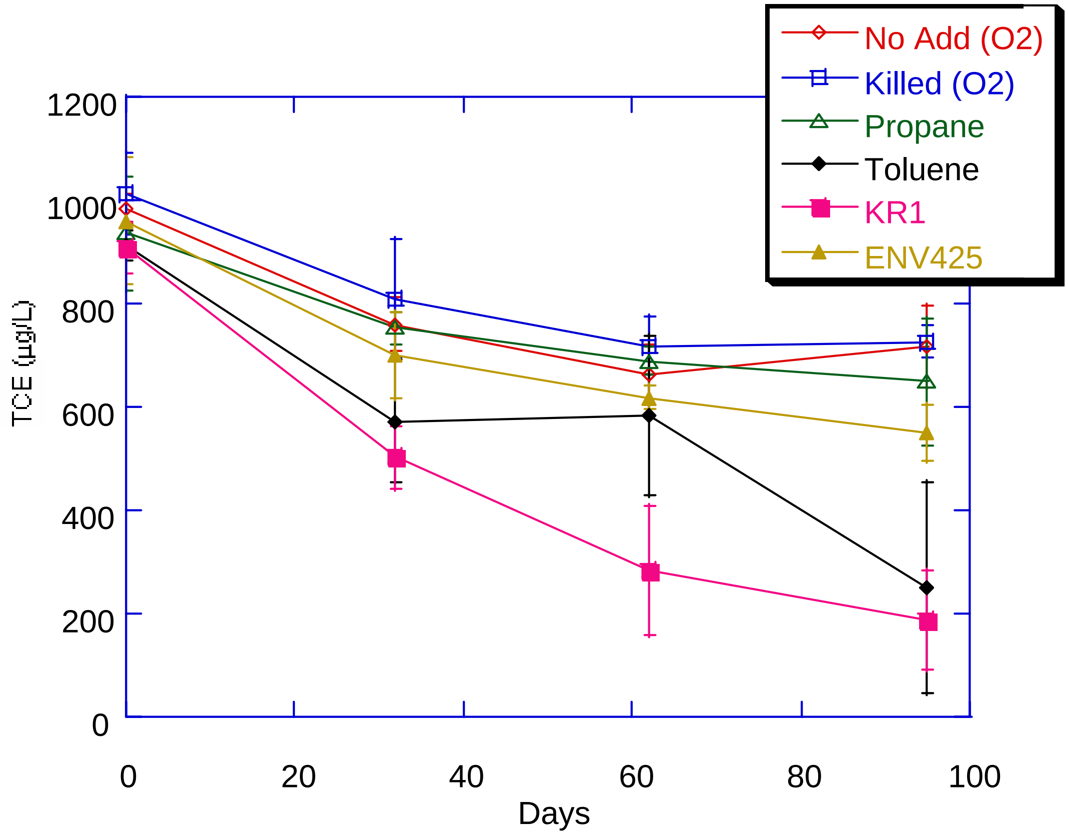
FIGURE 2

NDMA Concentrations in Aerobic PJKS Microcosms



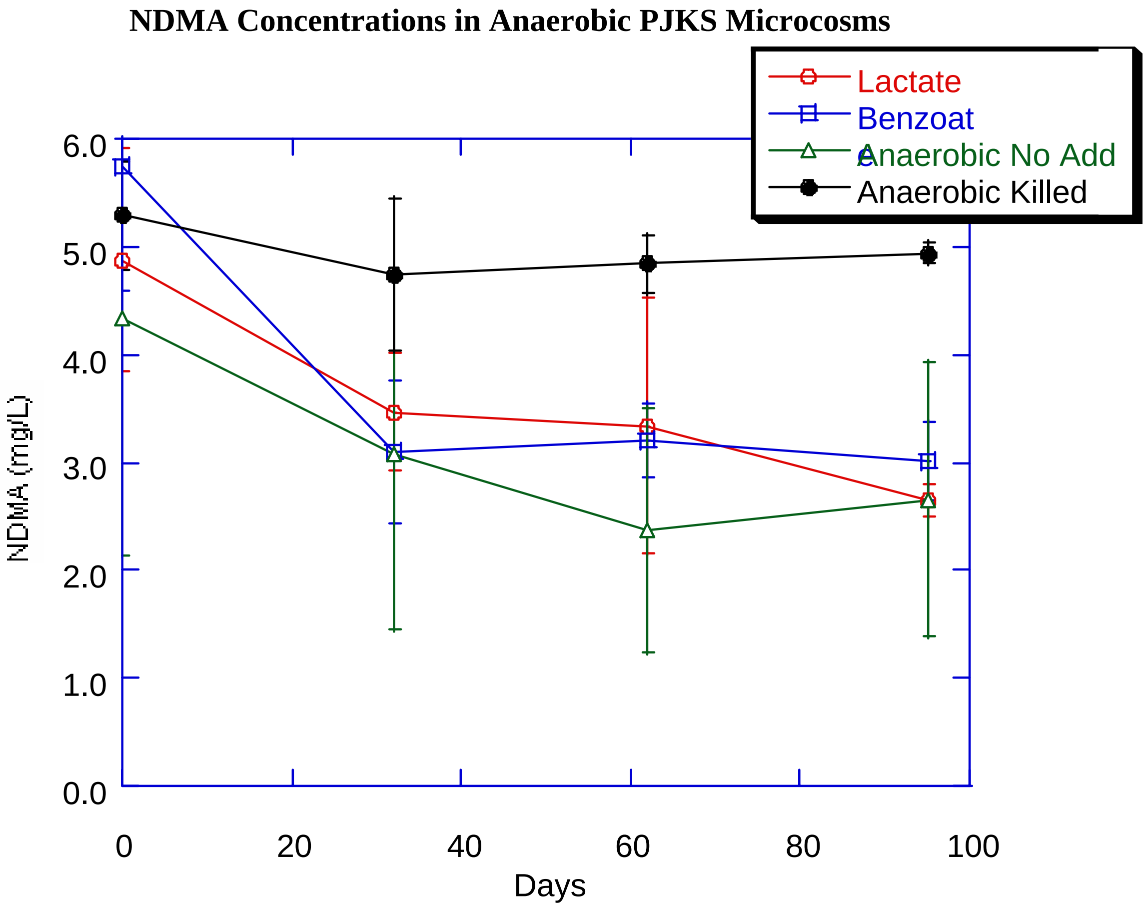
After three months, little reduction in NDMA is apparent in the various treatments. One week after the two-month samples were collected, inorganic nutrients were added to two of the three bottles in each treatment to determine whether nutrients may be limiting degradation of the co-substrate (i.e., propane or toluene), and subsequently preventing NDMA loss in these treatments. The nutrient addition resulted in a rapid decline in toluene levels in all samples receiving this amendment. However, the nutrient amendment had no appreciable effect on NDMA degradation. It is possible that the toluene-oxidizing bacteria are preferentially degrading the TCE first and that NDMA degradation will commence once TCE degradation is complete.

FIGURE 3
Trichloroethene (TCE) Concentrations in Aerobic PJKS Microcosms



After three months of aerobic shaking at 10°C, significant reductions in TCE are apparent in the bottles augmented with toluene and with *P. mendocina* KR1, as evidenced by the lower TCE concentrations in these bottles relative to the killed control samples. TCE levels in the other treatments are not appreciably different from the killed control samples.

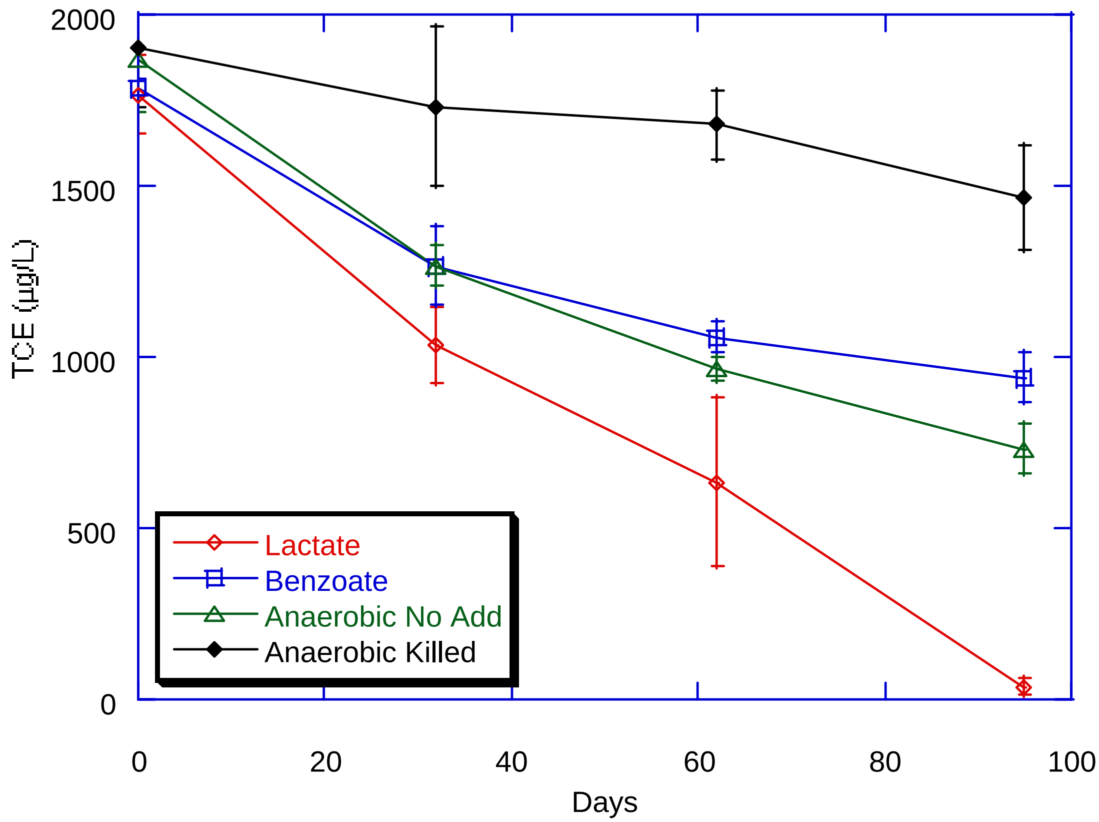
FIGURE 4



After three months under anaerobic conditions, NDMA continues to slowly decline in the lactate-amended microcosms. The NDMA levels in the benzoate-amended microcosm remained nearly the same after an initial decline during the first month. The NDMA levels in the live (unamended) microcosm continued to decline for 60 days and then leveled off.

FIGURE 5

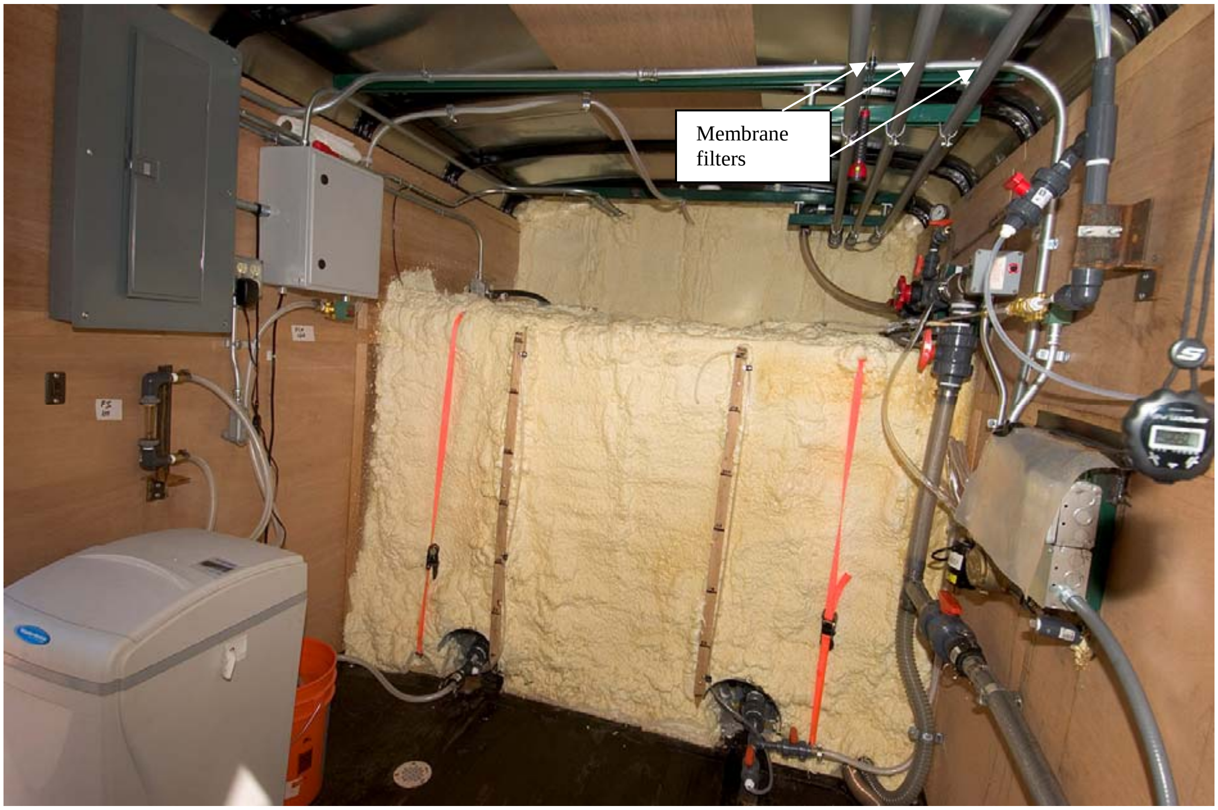
Trichloroethene (TCE) Concentrations in Anaerobic PJKS Microcosms



After three months, levels of TCE in all of the anaerobic treatments (no addition, benzoate, and lactate) are significantly reduced compared to the killed control samples. The largest reduction has occurred in samples treated with lactate, in which TCE has declined to < 40 µg/L. The TCE decline in the live control (no additions) relative to the killed control indicates that some natural attenuation may be occurring. The fact that the live control and the benzoate-amended bottles have essentially the same rate of reduction indicates that the benzoate is most likely not enhancing TCE degradation.

FIGURE 6
Photograph of Treatment Trailer (May 2006)

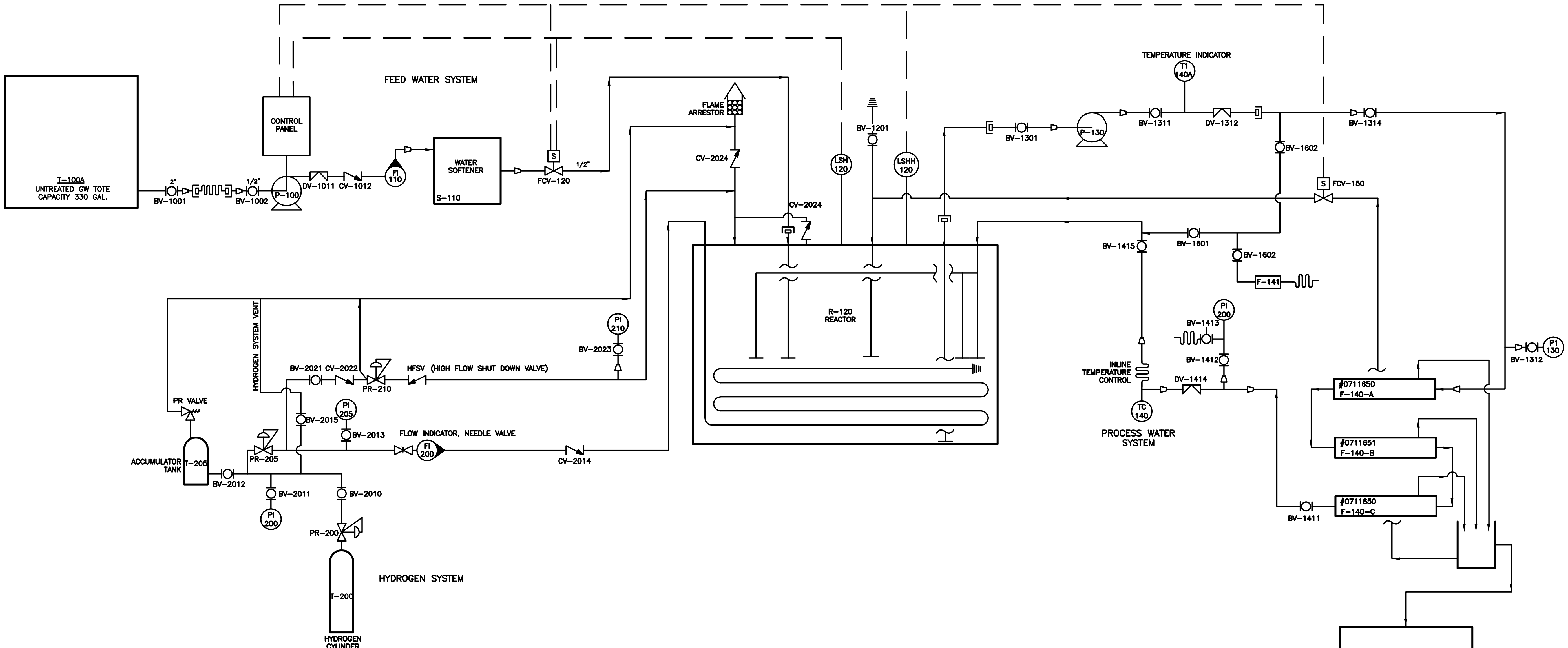
FIGURE 7
Photograph of Inside of Treatment Trailer (May 2006)



Inside of treatment trailer showing the pre-treatment and post-treatment water storage tanks, water softener systems, membrane filters, and associated piping (May 2006).

FIGURE 8
Photograph of Hydrogen Component Side of Treatment Trailer (May 2006)

Hydrogen component side of treatment trailer, showing nickel catalyst reactor with stainless-steel drum (May 2006).



LEGEND

- BV-XXXX — BALL VALVE
- CV-XXXX — CHECK VALVE
- DV-XXXX — DIAPHRAGM VALVE
- FCV-XXX — FLOW CONTROL VALVE
- NV-XXX — NEEDLE VALVE
- PR-XXX — PRESSURE REGULATOR
- PR VALVE — PRESSURE RELIFE VALVE
- SPRAY NOZZLE
- F-XXX — CARBON FILTERS
- #0711650 F-XXX-A — MEMBRANE FILTERS
- FI XXX — FLOW INDICATOR
- PI XXX — PRESSURE INDICATOR
- TI XXXX — TEMPERATURE INDICATOR
- LSH XXX — LEVEL SWITCH-HIGH
- LSHH XXX — LEVEL SWITCH-HIGH, HIGH
- P-XXX — PUMP

REVISION	DESCRIPTION	CHECKED	APPROVED	DATE
0	ISSUED TO AGENCIES	LWA	PSM	10/05/07

THE AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT
BROOKS CITY-BASE, TEXAS

FORMER AIR FORCE PLANT PJKS

FIGURE NUMBER 9

CATALYTIC NDMA TREATMENT FIELD DEMONSTRATION SYSTEM

Shaw Environmental, Inc.

	BY	DATE		BY	DATE	PROJECT NO.	REV.	FILE NAME
DSND	LWA	04/03/07	CHKD	DM	05/09/07	101372.2B100	0	101372D030
DRAWN	MEC	04/03/07	APPR	PSM	05/09/07			

APPENDICES

NDMA Field Test unit

"Rite in the Rain"®
ALL-WEATHER
FIELD BOOK
No. 350

CONTENTS

PAGE	REFERENCE	DATE

"Rite in the Rain"®
ALL-WEATHER WRITING PAPER

ALL-WEATHER
FIELD BOOK

Name Shaw Environmental, Inc.

Address 9201 E. Dry Creek Rd
Centennial, CO 80112

Phone

Project PJKS NDMA Field Test Unit
Logbook Contributors
Doug Bryant DB Mike Johnson MJ
Terry Rolon TR
Joe Franzen JF
Erica Koch EK

This book is printed on "Rite in the Rain" All-Weather Writing Paper - A unique paper created to shed water and enhance the written image. It is widely used throughout the world for recording critical field data in all kinds of weather. For best results, use a pencil or an all-weather pen.

Specifications for this book:

Page Pattern		Cover Options	
Left Page	Right Page	Polydura Cover	Fabrikoid Cover
Columnar	1/4" Grid	Item No. 350	Item No. 350F

(2.)

4-18-06

NDMA Treatment Unit

weather 35-60 Partly cloudy, gusty.

Goal: Place nickel into treatment unit and start up unit. Late entry 5-15-06 ADD ≈ 800 grams

0700) Arrived @ site

personnel: Doug Bryant, Terry Rulon, Doug Watt, Erica Koch

1100 Place nickel into unit. flow Rate Through filters slowed to ≈ 1/35 sec. per filter.

2100 Turned Hydrogen unit on

300 Determine That Solenoid from filter needed to Be enlarged

500 End of Day

DB

(3)

4-19-06 NDMA treatment unit

wether 35-65 Party cloudy gusty

Goal ~~Placed~~ Replace Solenoid from filters place ground water into system & Start-up unit & Collect Samples

~~0700~~ DB

personnel D. BRYANT, terry Rulon, D watt, Lavell SCOTT,

0700 arrived @ site.

0900 Started 1st Fire water cycle
Timer 1 - ~~3:48 min~~ 63 min
Timer 2 - ~~2~~:57 min

1400 Started 1st well water Cycle

1730 End of Day

Late Entry 1300 transferred 330 Gal from SS tank to Tank T-100 Infuent

DB

(4)

4-20-06

NDMA Treatment unit

Purpose Operate NDMA unit

personnel D. BRYANT, D WATT, Terry Rulon, E. Koch

weather 35 - 65 sunny calm

700 arrived @ site.

0930 Collect DO + HARDNESS + nitrate screen

1045 Recycle Line Back to Reactor stopped flowing. ~~Bro~~ cracked fill port and flow Began Again.

1400 collect full suite of Samples influent + Effluent.

1730 End of Day

DB

(5)

4-21-06

NDMA Treatment unit

Purpose: Operate NDMA unit

personnel D. BRYANT, T. Rulon, E. Koch

weather 35-65 Sunny Calm

0700 ARRIVED @ Site

0720 Took first set of Readings Problem with Vacuum Re-accured in the Re-cycle Permeate Line.

1030 Transfered ≅ 140 Gal from T-150 (Effluent) to Transport Tank.

1100 Pulled Sample and Took flow measurement

1200 stopped unit To Place gasket in electrical Plug

1230 Restart

1630 ~~Sh~~ End of Day

DB

⑥ 4-24-06
Monday
NOMA trial

Purpose: Run NOMA trial unit
Weather: ~~Rain~~ Rain/Snow mix
32-40 Cloudy
Personnel: D. Bryant, E. Koch,
Terry Rulon

0700 Arrived @ site
0800 Turned on unit Timers 257 + 63 min.
1130 Pulled effluent sample
1410 Pulled Influent sample
1702 End of Day

DD

4-25-06
Tuesday
NOMA trial
⑦

Purpose: Run NOMA trial unit
Weather Snow 28-50 mostly cloudy
Personnel D. Bryant, E Koch, T. Rulon
0700 Arrived @ Site
1110 Sampled
1700 End of Day

DD

⑧ 4-26-06
WED

NDMA field Trial

Purpose – Run NDMA unit
weather – 30 – 65 Partly Cloudy
personnel D. BRYANT, J. Rulon, E Koch

0700 Arrived @ site
1110 Collected Sample
1700 END of DAY

DB

⑨

4-27-06
Thur

NDMA field Trial

Purpose – RUN NDMA UNIT
weather 45 – 75 clear calm
Personnel D. BRYANT, T Rulon.
0700 Arrived @ site
1045 Collected Sample
1700 END of DAY

DB

(10)

4-28-06 NDWA Test Unit
Friday

Purpose: Run NDWA Unit.
weather 32-50 Rainy calm
personnel BRYANT, Lavell

0700 Arrived @ site
1115 Pulled Samples
1323 Shut unit Down at Beginning
on next fill cycle.
1700 End of Day

10B

5-1-06 (11)

Monday NDWA Test Unit

purpose Run NDWA Unit
weather 40-75 Partly Cloudy
Calm
personnel BRYANT, Rulon, Lavell
0700 Arrived @ site
1550 Sampled EFF 4009 mwH
1700 End of Day

Late Entry - Installed New
Regulator & Effluent
Tank flow meter

DB

12 5-2-06

Tues NDMA Treatment Unit

purpose: Run NDMA treatment Unit

weather 45-80 sunny clear

Personnel D. BRYANT, T. Rulon, S. Lovell

0700 Arrived @ site: Accumulator Tank still had 25 PSI

0800 Collected Samples EFF4008

1700 End of Day

DB

5-3-06 NDMA Treatment Unit

Wed.

Purpose: Run NDMA treatment unit.

Weather: 45-55° part sun - turning to ~~ek~~ rain/drizzle.

Personnel: T. Rulon, S. Lavell, L. Archibald, E. Koch

0700 Arrived @ site. Assisted T. Rulon with readings on unit. Water levels look good.

0810 Collected samples EFF4011, EFF4033 (FD) ~~and INF4003~~, ~~INF 4032 (FD)~~ EK 5/3/06

1155 Added water from Stainless Steel tote to influent tank.

1245 Sampled INF4003 and INF4032 (FD)

1700 END of Day

EK

5-4-06 NDMA Treatment Unit
Thurs.
Purpose: Run NDMA treatment Unit
weather: 45-50° partly cloudy
personnel: T. Rulon, S. Lavell,
E. Koch

0700 Arrive onsite.
0800 Take water flow rate and notice flow is still slower than expected.
0940 Sample EFF4010. MWH samples labeled EFF4010 + EFF4010-01 for FD.
1120 Another cycle begins on unit and still notice timers are slightly off. Take another flow rate and flow still slower than expected.
1420 T. Rulon increased flow rate across permeate membrane filters.
1630 Take another flow rate. Looking better.
1700 End of day

EK

5-5-06 NDMA Treatment Unit
Friday
Purpose: Run NDMA treatment unit
Weather: 40° - rain-cool
Personnel: T. Rulon, E. Koch,
~~L Scott~~ S. Lavell

0700 Arrive onsite.
0800: Take water flow measure and rate is still slighty lower than expected.
0905: ~~Fosk~~ Sample EFF4012 - only NDMA - no MWH.
1100: Second cycle begins. Take water measurements - still slow. Shut unit down for weekend.
1700: End of day.

EK

(16)

5-8-06

Monday NDMA field Test Unit

Purpose Run NDMA unit

weather 45-72°, Partly cloudy some Rain.

personnel D. BRYANT, T. Rulon, E Koch, James ford

0700 Arrived @ site James ford To Pump ground water

0900 flow Rate very slow. 2-3 GPH. ~~Deci~~ it was Determined not To Turn unit on, But To Replace filters instead. Drum was Pump Down ≈ 20 gal, To facilitate flushing filters Prior to Replacement.

1700 End of Day

DB

(17)

5-9-06

Tue NDMA field Test unit

Purpose flush filters

weather 50-65 Partly sunny

personnel D. BRYANT

0700 Arrived @ site unit not Running Today.

1300 modified system To allow filter To Be flushed

1700 End of Day

DB

(18)
5-10-06
WED NDMA Field Test unit
purpose Replace membrain filters
weather 31 - 58 overcast Calm
personnel D. BRYANT

0700 Arrived @ site

1400 Removed membrain filters
1700 End of Day

DB

5-11-06 (19)
Thur NDMA field test unit

0700 Arrived @ site. unit
Down awaiting filter to arrive
Delivery expected 5-12-06
1700 End of Day

DB

20 5-15-06

Monday: NDMA field Test unit

purpose change out membrane filter and start unit

weather 45-75 sunny calm

personnel P. BRYANT, E. Koch, C Scott T. Ruloc

0700 ARRIVED @ site

0800 filter Did not come in on friday, should Be in this morning

1100 filter arrived at site and were installed

1700 End of Day

DB

5-16-06 (21)

Tue NDMA field Test unit

~~purpose~~

purpose: Start & Run field Test unit with new filters

weather 45-78 sunny calm

personnel P. BRYANT, E Koch

0700 ARRIVED @ site

0900 flow Rates Low of 45gpm and High of 135gpm Spoke with Watt and Ruloc Decided To Replace 2 of The new filter with 1 Neg & 1 neutral old filters

~~0~~ DB 1630 Completed Reinstalation

1700 End of Day

DB

5-17-06 (22)

WED NDMA Test Unit

Purpose Run NDMA Test Unit

Weather 54-83 Sunny Calm

0700 Arrived @ Site

0720 Started units & Took Beginning Reading

1230 Had Problem with Timers And Re-set Timers.

1430 Again Had Problem with Timers And Had to Re-set

1630 Did not trust Timer So we shut Unit Down And Flushed.

1700 End of Day

Late Entry GW pumps shut Down for After noon Due to Testing @ T-27

DB

5-18-06 (23)

Thur NDMA Test Unit

Purpose Run NDMA test Unit

Weather 55-85 Sunny Calm

0700 Arrived @ Site

0800 Turned Unit on And set Timers

1150 Pulled Samples

1700 End of Day

DB

5-19-06 (24)

Friday NDMA Test unit
Purpose - Run NDMA Test unit
weather 50-90 Sunny Calm
personnel - D. BRYANT, E Koch, L. Scott

0700 Arrived @ site

1110 ~~St~~ Sampled

1130 Spoke with Bruce about Hydrogen Storage. Bruce said to Store on Pad Next To Building North of TIA. Bruce said That no Shelter was Required And That The Tanks Could Be Stored in Direct Sun for The Duration of The NDMA

1700

DB

5-22-06 (25)

Monday NDMA Test unit
Purpose - Run NDMA Test unit
weather 50-90 Rain in After noon
personnel D. BRYANT, E Koch, L. Scott, T Rulof

0700 Arrived @ Site

1110 Pulled Sample

1700 END of Day

DB

(26) 5-23-06

Tue NDMA field unit

Purpose Run field unit
weather 50-90 Sunny
personnel D. BRYANT, E. Koch
L. Scott

0700 Arrived @ Site

11:00 nitrate Levels still
elevated

1500 Decided with Pat McGrain
That we would Pull
A NDMA Sample & A
nickel slurry Sample
Then Shut Down ~~unit~~ the
To figure out what is
wrong with system

1700 End of Day

DB

5-24-06 (27)

Wed NDMA field unit

Purpose Shut Down NDMA
Unit
weather 50-90 Sunny
personnel D. BRYANT, E. Koch
L. Scott

0700 Arrived @ Site
~~Pulled Dn~~
0715 Pulled NDMA Sample
And a nickel slurry
Sample

0930 shut unit Down
Pumped Drum Down to
± 20 gals & flushed
system

1700

Late Entry 1300 opened Drum
And observed inside
nickel was caked on
most of ~~interior~~ interior
Parts. Low Parts
Had a greenish
color to the
nickel, NO
Unusual Build up of nickel on ~~bottom~~ Bottom
of Drum.

DB

(28) 5-25-06

Thur NDMA field unit

Purpose find out why NDMA unit not working

weather 50-90 Sunny

personnel D. BRYANT, L. Scott, ERICK Koch, T. Rulon

0700 Arrived @ Site

1700 End of Day

DB

5-30-06 (29)

Tue NDMA field unit

purpose Sample green material on Lower Part of Stingers inside Reactor

weather 50-70 Partly cloudy

personnel D. BRYANT, E. Koch, L. Scott, T. Rulon

0700 Arrived @ Site

0845 Pulled Sample of green material on Lower Part of Stingers inside Reactor collected 1 TO 2 grams. material was A Olive green Color. PH of water Remaining in Drum was ph7.

1700 End of Day

DB

7-18-06 T. Ruben - Solo

SWITCHED OUT VARIOUS SYSTEM COMPONENTS BELIVED TO BE CAUSING GALVANIC CORRESION ISSUES AND BREAKDOWN OF NICKLE CHANGED OUT R-120 FOR POLY (EXCEPT FOR LID) LSH-120 + LSHH-120 WITH PLASTIC FLOAT SWITCHES, AND REPLACED CAMLOC FITTINGS AND ALUMINUM AND BRASS FITTINGS ON STINGERS (R-120) AND CAGE FOR TEFLON TUBING. REPLACEMENT PUMP FOR P-130 SHOULD BE HERE 7-20-06, PLASTIC PUMP.

1500 OBTAINED 170 GALLONS OF FRESH H_2O FROM M-7, TRANSFERED INTO T-150A FOR PRE-START-UP OF UNIT.

1600 FILLED R-120 WITH WATER NO HYDROGEN OR NICKLE IN USE AT THIS TIME.

CHECKED TIMING SEQUENCE + FLOAT SWITCHES (NOT WORKING PROPERLY) CHECKED MEMBRANE FILTERS (PERMEATE) FLOW RATE & OPERATING PRESSURES.

TW

7-19

Continued checking system components.

Installed new R-120, Poly Prop. 55 drum, Installed new silicon tubing on Re-fabricated PVC cage. Pulled all cam lock fittings off of R-120 lid switch out with PVC nipples threaded directly into lid. Switched out hydrogen system components 2 - 1/3 psi check valves replace with 2 - 1 psi check valves. Run system with fresh water check timing sequence, fill and drain cycles -

Float switches appear to be malfunctioning, water level in R-120 over flowing during fill cycle -

TW

7-20-06 Rulon Solo
Continued checking out system components and trouble shooting problems. During fill cycle, pressure builds up inside R-120 preventing Permeate from membrane filters to flow into R-120

10/4/06 Wednesday

EK, JF, TR. STARTED SYSTEM w/ Ni. TR ADDED Ni @ 0645. STARTED SYS. CYCLE. TOOK 1ST READING @ 0752. FLOW RATE 13.32 g./min. ~~T~~EMP. = 65°F HARDNESS 4.0 pH = 7.0

11:30 Sampled influent tank - INF4004 for NDMA, Diss. Nickel, Total Nickel VOCs and Common Ions.

1145 Sampled Effluent after cycle 2 (0900 - 1200) EFF4017. Sampled for NDMA, Diss. Nickel, Total Nickel, VOCs and Common Ions. Two NDMA Samples sent to MWH.

Did not take Nitrate test w/ strips b/c may have gotten wet. Not working properly.

Set timers from Return to drum (RTD) 1 hour to 6.5 hours and Return to Effluent (RTE) from 2 hours to 1.5 hrs. @ 16:00.

1700 End of day

EK

10-5-06 Thursday

Field Personnel: T. Rulon, J. Franzen, J. Ford, E. Koch

0700 T. Rulon checks system and notices timers are off. May not have been treating correctly. Re-sets.

0800 T. Rulon figures out hyrdogen pressure keeps building up in drum, causing other timer to start counting.

1130 Take influent water readings. Hardness = 250ppm, Nitrate = 3ppm and pH = 7.0.

1145 Effluent water readings Hardness = 0, Nitrate = 3ppm, PH = 8.0

1325 Sample Effluent - Cycle 6 for MWH - NDMA only

1545 Flow rate = 15.65 gallons/min

1600 Set timers again for 6.5 RTD, 1.5 RTE.

1700 End of day

EK

10-6-06 Friday

Field Personnel: T. Rulon, J. Franzen, E. Koch

0700 Timers off again. T. Rulon decides to finish cycle and figure out where problem is in drum.

0730 J. Franzen pumps in 75 gallons - disposes of 119 gallons

0815 Water flow redding taken

0820 Hardness = 0, Nitrate = 3ppm pH = 7.0

0840 Sample dissolved nickel + total nickel (EFF4019) cycle 8.

0900 T. Rulon talks to Charles Schaefer about high nitrate levels. Decide not to send NDMA to MWH.

1130 Take another nitrate reading - still high - will let cycle finish + bleed down drum.

1400 J. Franzen + E. Koch ~~purk~~ flush nickel from filters.

1500 Open drum to look for where hydrogen is escaping.

1700 End of day

10/7/06 TR, JF

ARRIVE @ 0800 SUNNY 60°F.
DISCONNECTED BLUE DRUM
REACTOR. CLEANED OUT REACTOR.
FOUND LEAK @ END OF TUBING.
PREVIOUSLY USED WRONG CABLE TIE
THAT CREATED LEAK. RE-SEATED
END CAP. PRESSURE TESTED
FEED TUBING. RE-INSTALLED
BLUE REACTOR DRUM. @ 1130.

JF
10/7/04

10/~~8~~ 9/06

COLD RAINY, 40°F. FILLED
REACTOR. PRIMED PUMP P-130
CIRCULATED H_2O THROUGH
SYSTEM WHILE PURGING AIR.
ADDED 1 lb. OF Ni TO CLEAN
H_2O. INTRODUCED Ni to
SYSTEM. APPROXIMATELY 1/4
lb. OF Ni REMAINED IN
SYSTEM. CIRCULATED Ni
through system. TOOK H_2O
SYSTEM PARAMETERS @ 1430
HARDNESS = 0 NITRATE = 2.0 pH = 6.5
DO = 1 ppm 2nd SET @ 1600
HARDNESS = 0 NITRATE = 2.0 pH = 7.5
DO = 1 ppm. FLOW RATE = 10.34 g/HR.

JF
10/9/04

10-10-06 Tuesday
Personnel: D. Bryant, J. Franzen, E. Koch
T. Rulon
Arrive @ 0700. Cold, cloudy ~40°
Take water readings. Hardness = 0,
Nitrate = 0.25, pH = 8.5, + DO = 1 ppm
DB speaks w/ C. Shaefer @ 0900
and suggests changing out 473P
Nickel and replace w/ original
powdered nickel ~ 500 grams.
J. Franzen + DB take unit
apart to clean + remove old
nickel.
Will be ready for startup on
Thursday morning

EK
10-10-06

10-11-06 Wednesday
Personnel: D. Bryant, J. Franzen
E. Koch, T. Rulon
0700 Arrived @ site finished
cleaning out system of 473P
nickel. Filled with water and
ran for ≈ 2 hrs before
adding 800 grams of original
nickel powder.
1430 checked readings
DO - 1ppm nitrate = 2 and
Hardness = 180. Determined
water softener not work
as desired. Discussed with
Team and determined that
we run overnight and
Regenerate softener when
we shut down unit Thursday night
for ~~Repair~~ the weekend.
0500 Left site

DB

10-12-06 Thursday

personnel - D. BRYANT, J. FRANZEN

E. Koch,

0700 ARRIVED @ site, found The ~~FTP~~ containment system was full of water. further inspection showed that nickel water was leaking from The Pump And ~110 Gallions of water Had Leaked into the containment system. Unit shut-down Begain clean-up. Reported situation To T. Cooper, P. moore Bruce wainwright. T. Cooper To call Vicki Anderson.

1500 ~~0300~~ DB cleaned trailer, Pulled Pump and Drop off @ ARVADA Pump

1700 ~~0500~~ DB End of DAY.

DB

10-16-06 MONDAY

personnel D. BRYANT, J. FRANZEN

E. Koch.

0700 ARRIVED @ site

0800 Spoke with Kent from ARVADA Pump. Kent Said ~~the~~ Seals were worn and should Be Replaced. Kent will order seals for Pump for ~~and~~ Delivery tomorrow and Pump should be Ready To install wednesday morning.

~~500~~ DB 1700 End of Day.

Late Entry Re-charged water softener

DB

NDMA Treatment unit

10-17-06 Tuesday

Personnel, D. BRYANT, J. FRANZ E. Koch

weather 30-50 cloudy Rain / SNOW

0700 ARRIVED @ site

0900 Had Mike Hammerman sign wast manifest for Disposal of IDW waste Related To Drilling Activities

1700 END of Day

Late Entry - 1500 J. FRANZEN Picked up Repaired Pump.

DB

NDMA Treatment unit

10-18-06 ~~wed~~ DB Wednesday

Personnel - D. BRYANT, J. FRANZEN E Koch.

weather 30-45 Partly cloudy

0700 ARRIVED @ Site and installed Pump with new Seals. ~~Started~~ DB Primed System and started System After Run for short Period of Time Pump started Leakin Kent FROM ARVADA Pump Said To Remove Pump and Bring in to Him, After inspection it was Determined That The new Seals Do not Disipate The Heat as well And Uless we Remove 100% of AIR During Priming That the Seal Housing will overheat And Become Distormed. New Start up Procedure will Be Developed, Kent checking of ~~1700~~ DB Repair Cost + schedule

1700 END of Day

DB

10-19-06 Thursday

Personnel. D. BRYANT, E Koch, Jo FRANSON
weather 30-45 overcast

0700 Arrived @ Site

1000 Kent from Arunda Pump Called and said he was Looking for Parts to Repair Pump. He did not Know when he would have The Pump fixed But Though it would Be monday or Tuesday (10-23 or 10-24).

1700 End of Day

DB

10-23-06 Monday

No work on NDMW Unit Performed Today - Pump in for Repairs. Drilling waste shipped off-site. By ACT (2 trucks) Remainder of waste to be shipped of Tuesday and ~~wkds~~ Wedsday.

DB

10-24-06 Tuesday

Personnel – D. BRYANT, J. FRANZA
weather 45-65 Partly cloudy

0700 Arrived @ site And installed Repair Pump. During Priming Process cracked Bleeder Plug Case. Called Arunda Pump. Arunda Pump said to glue together with "Plast-aid" Plastic Repair Compound. Let unit Run untill Repair Could be made

1300 To field measurements DO =<1, HARDness 40 ppm Hardwater ~~sit~~ still in Drum from Last week. Nitrate = 125

1530 shut unit Down And Repair Pump

1700 END of Day

10-25-06 ~~Wed~~ Wednesday

Personnel D. BRYANT, J. FRANZA
weather 40-60 Partly cloudy

0700 Arrived @ site And started Pump To DRAIN unit

0900 Took field measurements HARDness 40 ppm, DO =<1 PH 7, nitrates = 0

1400 Add 500 grams of nickel To System

1700 End of Day

DB

NOMA UNIT

10-26-06 Thursday
Weather 30, Heavy snow
Personnel - D. Bryant,
J. Franzen

0700 Arrived @ site
0800 Took field readings
Before end of cycle
nitrate = 0 D.O. 21

1350 - 10 minutes before the
RTD of the 3RD cycle
was to begin, site power
went down do to weather

1700 Power ~~sitt~~ still down
at end of day

DB

NOMA Unit
10-27-06 Friday
Weather 30 - 50 Clear Sunny
Personnel D. BRYANT, J. FRANZEN
0700 Arrived @ site and
started unit up. Drained
DTE Tank for 1.5 hrs to
add new water before starting
cycle 4.
1330 Joe changed out Hydrogen
Tank.
1500 Collected samples @ EFF 4021 DA
and shipped to MWH
1630 Shut unit down for the
weekend.
1700 End of Day

DB

10-30-06 Monday
personnel D.B. E.K. JF
weather 25-45 Partly Sunny

0700 Arrived @ Site and Started NDMA Unit.
1400 Collected Sample 4022
1500 ship sample to MWH and nickel water Sample To Charlie Schaeter
1700 End of Day

DB

10-31-06 Tue.
personnel DB, EK, JF
weather 25-40 Partly cloudy
0700 Arrived @ Site
0710 Collected NDMA Sample Charles Schaeter said not To send. And that we should Collect sample on new 4-2 schedule
0800 Started 4-2 schedule
1700 End of Day

DB

NDMA Unit

11-1-06 wed

personnel DB, JF, EK

weather; 20-40 Partly Sunny

0700 Arrived @ site To operate NDMA Unit

1000 everything working normal

1700 End of Day

DB

NDMA Unit

11-2-06 thur

personnel DB, JF, EK

weather 20-50 Partly Sunny

0700 Arrived @ site

1700 End of Day

note; elevated ~~with~~ Hardness in effluent

DB

11-3-06 Fri

personnel - DB, JF, EK

weather 30 - 50 Partly Cloudy

0700 Arrived @ site

0800 Elevated Hardness in effluent

1400 Shut Down Unit for weekend. Attempt To Regenerate Softener. Re-generation Failed

1700 End of Day

DB

11-6-06 Mon

personnel - DB, JF, EK

weather 35 - 65 Sunny

0700 Arrived @ site

Called Technical Services person @ water Boss water softener. Took apart unit and cleaned Parts. Also Hooked unit up to injection Pump used for ground water injection to ~~inck~~ increase pressure To Unit. Re-generation was successful

1600 Start-up unit.

1700 End of Day

DB

NDMA Unit

11-7-06 Tue
personnel DB, SF
weather 55-75 sunny

0700 Arrived @ Site
NDMA Unit working
good.
1700 End of Day

DB

NDMA Unit

11-8-06 Wed
personnel DB, SF
weather 60-78
0700 Arrived @ Site
NDMA Unit working
good.
1300 Collected Sample EFF-4025
1700 End of Day

DB

11-9-06 thur

Personnel DA, JF
weather 40 - 60 Partly Sunny

0700 Arrived @ site
Everything Good
1700 End of Day

DA

11-10-06 Fri

personnel – DB, JF
weather 30 - 50 Sunny
0700 Arrived @ site
Unit Running well

0800 "other Project" Began
installing monument @
T-23, valve shop, T-27.

1700 end of Day

DB

62 NDMA Unit

11-13-06 Mon
Personnel D.B, JF, EK
weather 28-55 mostly sunny

0700 Arrived @ site
0900 Collected influent
sample INF 4005
Dup INF 4020
1700 End of Day

DB

NDMA Unit 63

11-14-06 Tue
Personnel D.B, JF, EK
weather 40-55 Partly sunny
very windy.

0700 Arrived @ site
0715 Collected NDMA sample
EFF4027 MW14
every Running well
0800 changed cycle time
To 3.5 RTA and 2.5 DTF
1700 End of Day

DB

11-15-06 WED

Personnel JF, DB, EK

weather 25-45 Partly Sunny

0700 Arrived @ Site

1700 End of Day

DB

11-16-06 Thur

Personnel JF, DB, EK

weather 25-50 Partly Sunny

0700 Arrived @ Site

1200 Collected Samples

EFF 4025-site and EFF 4028-multi

1700 End of Day

DB

4125-
28 multi

11-17-06 Fri
personnel IF, D.B, EK
weather 40-60 sunny
700 Arrived @ Site
1400 shut unit Down for weekend. flushed filter. Pumped 4 foam Balls Through "B" filter ~~and Re-installed "B" filter.~~ pump Did not Have enough pressure To Push foam Balls Through filter. Test failed
1700 END of Day

11-20-06 Mon
Personnel DB, IF, EK
weather 35-65 Partly Sunny
0700 Arrived @ Site
0800 Turned unit on with A 3.5 - 2.5 cycle time
1400 Changed cycle Time per Charlie's to 2-2 cycle Time.
1700 END of Day

11-21-06 Tue

personnel - DB, JF, EK

weather - 35°-65° sunny calm

0700 arrived @ site

1305 Collect NDMA sample To mull. ERF-4029-NDMA

1700 End of Day

DB

11-22-06 ~~Wednes~~ Wed

personnel DB, JF, EK

weather 35°-70° sunny

0700 arrived @ site - All is well.

1400 shut unit Down for the Holiday weekend.

1500 Regenerated water softener.

1600 Pumped 4 foam Balls Through filter "B" 3 ~~seperat~~ seperate Times.

1700 End of Day

DB

 NDMU Test Unit

11-27-06 mon

personnel - DB, JP, EK

weather 20-45 mostly sunny

0700 Arrived @ site.

0800 Turned unit on.
Took flow measurements "B" filter seems to have flow rate increase of ≈ 3 fold. ~~"A" filter was~~ Due to cleaning with foam balls. "A" filter was ≈ 120 ml/min and "B" was ≈ 380 ml/min. Normally both filter are very close in flow rate

0830 Had problem with effluent Solinode. Played with switches for 30 min. and solinode started to work. Do not know what I did?

0900 start cycle 07

continued on next page

NDMU Test Unit

11-27-06 mon (continued)

1500 Took nitrate field test reading ≈ .5. it appears that the unit is not work effecively.
~~1500~~ shut unit down and opened lid. Took stick and scraped ~~Rig~~ "b" Ring Holding Tubing. Some build up of nickel was found on Rings. noticed some nickel had stuck to side of drum. Also scraped side of drum

1520 Restarted unit.

1700 End of Day

DB

NDMA Test unit

11-28-06 Tue

personnel DB, JF, EK
weather 30-40 cloudy

0700 Arrived @ site and to field measurement on TL unit nitrate levels were 0 ≈ 2 hr into cycle. System seems to be working.

1200 ~~Collect~~ Collected full effluent sample set ~~EFF~~ EFF 4030.

1700 changed cycle time to 4-2 so we would not run out of water, next 2 days expected lows 5 / high 25°. Likely will not be able to pump for two days.

DB

11-28-06 WED

personnel DB, JF, EK
weather 15-25 snow + cold

0700 Arrived @ site

0900 Ground water was pump today. ≈ 70 gal

1700 End of Day

DB

NDMA test unit

11-30-06 Thu
personnell - DB, JF, EK
weather - 3-28 cold + sunny

0700 Arrived @ site

916 To NDMA sample to mcwit

1700 Pumped water today
End of Day

DB

12-1-06 Friday

Personnel: J. Franzen, D. Bryant, E. Koch
weather: clear, cold ~ 30° for high
0700: Arrive onsite. Check unit - everything running ok.
0800: J. Franzen leaves to pump groundwater.
1200: Measurements ok -
17:00: Flushed filters and shut unit down for weekend. Joe added ~~80~~ 50 EK gallons to influent tank

EK

12-4-06 Monday
Personnel: J. Franzen, E. Koch
Weather: mostly sunny, calm, 25° - high of 40°.

0720: J. Franzen & E. Koch turn pump on for re-circulation mode.
0800: Turn on hydrogen and start timers for 4 hr. treat & 2 hr. discharge.
0805: Take field readings at start. DO=<1, Nitrate = 0.25, Hardness = 0.
1400: New batch begins - cycle 88. Timers ok.
1700: Turn off hydrogen for evening - end of day,

EK

12-5-06 Tuesday
Personnel: J. Franzen, E. Koch
weather: Mostly sunny, slight wind, 31° - high of 50°.

0700: Arrive onsite check system.
0800: Re-adjusted timers - a little off - back to cycle Starting @ 08:00.
1300: Check system. Everything OK, nitrates = 0.
1700: Turn hydrogen off for evening. End of day

EK

12-6-06 Wednesday
Personnel: J. Franzen, E. Koch, T. Rulon
Weather: partly sunny, calm, 20° ~ high of 44°.

0700: Arrive onsite, T. Rulon adds 100 psi of hydrogen into tank. Everything ok.

0710: Readings are normal. Nitrate = 0.25, hardness = 0, ph = 8, DO < 1. Sample EFF4034-MWH for NDMA and EFF4034 - going to STL for Dissolved + Total Nickel.

0830: J. Franzen disposes ~ 123 gallons of effluent water @ M137.

1252: Another set of readings. Nitrate still @ 0.25, but flow slowing

1700: Turn off hydrogen for evening - system ok. Joe pumped ~ 100 gallons of water. End of day.

EK

12-7-06 Thursday
Personnel: J. Franzen, T. Rulon, E. Koch
Weather: sunny, cold, 19°, high of 40°.

0700: Arrive onsite. Turn hydrogen on. system check ok.

0710: Flow rate seems to be slowing & nitrate reading is 0.5 ppm.

0730: J. Franzen pumps in ~ 100 gallons into influent tank.

1235: System ok.

1240: Flow still seems to be slowing.

1700: Turn hydrogen off for evening. ~~J. Koch~~ J. Franzen pumps ~ 100 gallons of water. End of day.

EK

12-8-06 Friday

Personnel: J. Franzen, T. Rulon, E. Koch

weather: Sunny, clear 34°. high of 58°.

0700 - Arrive onsite. Turn hydrogen back on.

0710: Take Measurements - flow rate ~ 8.5 gallons/hr. Nitrate = 0.25. Hardness = 0.

1045: Regenerate water softener.

1400: Shut unit down for weekend

1430: Flushed filters and ran 4 foam balls through filter "B", three separate times. Re-installed filter.

1600: End of day.

EK

12-11-06 Monday

Personnel: J. Franzen, E. Koch, T. Rulon

Weather: Sunny, cooler, 30° - high of 40°.

0700: Arrive onsite

0730: Put unit in re-circ. mode - bleed air out of system.

0830: Turn on hydrogen and start 1st cycle for the week. Measurements ok. Nitrate = 0, Hardness = 0 & DO < 1.

0840: J. Franzen begins pumping @ III-2-MZ.

1400: Measurements ok. Flow rate has increased from cleaning filter "B" on Friday

1700: Turn off hydrogen End of day.

EK

12-12-06 Tuesday
Personnel: J. Franzen, T. Rulon, E. Koch
weather: mostly sunny, 30°, high of 50.
0700: Arrive onsite. Turn on hydrogen + check measurements. Everything ok.
0710: J. Franzen pumps in ~100 gallons into influent tank.
1400 CHECK MEASUREMENTS
NITRATE 1.0 WHICH IS HIGH BUT JUST STARTED CYCLE. FLOW ON "B" FILTER ALSO DECREASED SLIGHTLY. HYDROGEN TANK GETTING LOW.
1615 CHECK MEASUREMENTS
NITRATES BACK DOWN TO 0.5
"B" FILTER FLOW BACK UP.
~~END~~ TURN OFF HYDROGEN
50 PSI IN HOLDING TANK.
END OF DAY

JF
12/12/06

12/13/06 WED.
PERSONNEL: JF, TR, EK
WEATHER: SUNNY, 30, HIGH 50
0700: ARRIVE ONSITE TURN ON HYDROGEN & CHECK MEASUREMENTS. NITRATES HIGH @ .25 @ END OF CYCLE. WILL WAIT TO SAMPLE @ END OF SECOND CYCLE. HYDROGEN PSI LOW @ 300 PSI.
1415 REMOVED LID OFF REACTOR. SCRAPED N. off sides of DRUM AND TOP OF TUBING RACK. CHANGED HYDROGEN CANISTER. LET SYS. RUN. NO MEASUREMENTS COLLECTED.
1600 COLLECTED FULL SET OF MEASUREMENTS. NITRATES STILL HIGH @ 1.
FLOW RATE STILL STABLE.

JF
12/13/06

12-14-06 Thursday
Personnel: T. Kulon, J. Franzen, E. Koch
Weather: mostly sunny, 49°, high of 59°.

0700: Arrive onsite. Turn on hydrogen and take measurements. Nitrate = 0, Hardness = 0, DO < 1.
0800: Sample EFF4035 for Nickel ~~& NDMA~~ EFF4035-MW# for NDMA. TURN PSI UP ON HYDRO
1505: Take another set of measurements. Nitrate increased to 0.5.
1600: Sample INF4007 for NDMA only.
1700: Turn off hydrogen for evening. End of day.

EK

12/15/06 FRI.
PERSONNEL: JF, TR
WEATHER: SUNNY, WINDY, 55
0700 ARRIVED ON SITE TURN ON HYDROGEN COLLECT MEASUREMENTS NITRATE = 0 HARD. = 0 DO < 1. GOOD FLOW pH = 8.
0730 ADD 75 gal. to INFF.
0750 - DRAIN 150 gal. FROM
0830 EFF. TANK.
1200 FLUSH FILTERS AND SHUT DOWN FOR WEEKEND
1230 END OF DAY

JF

12-18-06 Monday
Personnel: J. Franzen, T. Kulon, E. Koch
Weather: Cloudy, cool, 30°
0700: Arrive onsite
0730: Turn unit on re-circulation mode.
0830: Turn on hydrogen and start treatment.
0835: Take measurements - DO = 1, Nitrate = 0. Hardness = 0.
1454 TAKE MEASUREMENTS. NITRATES UP TO .25 @ BEGINNING OF CYCLE. INCREASED FLOW FOR FILTERS B & C.
1615 TAKE MEASUREMENTS. NITRATES STILL @ .25 FLOW IN FILTER C DECREASED TURN OFF HYDROGEN. OPEN HYDRO. HOLDING TANK.
END OF DAY

JF
12/18/06

12-19-06 Tuesday
Personnel: J. Franzen, T. Kulon, E. Koch
Weather: partly Cloudy, 40°
0700: Arrive onsite
0730: ~~Turn unit on~~ Turn hydrogen on.
0800: Timers off a little, will let drain + re-set @ 10:00.
1000: Re-set timers (4 RTD + 2 RTE)
1600: Scraped nickel off sides of drum to get it more agitated.
1700: End of day.

EK

12-20-06 Wednesday
Personnel: J. Franzen, E. Koch
Weather: cold, snowing - expecting blizzard conditions through-out day.
0700: Arrive onsite
0900: Sampled ~~INF4008~~ EK EFF4036 for Nickel to STL & EFF4036-MWH for NDMA.
0910: Sampled INF4008 for NDMA to STL.
1000: Flush filters and shut unit down for holiday. Weather conditions worsening - will not run unit on Thursday.
1200: End of day

EK

1-3-07 Wednesday
Personnel: T. Rulon, E. Koch
Weather: mostly cloudy, 38° - high of 50°.
0700: Arrive onsite
0745: Turn unit on re-circ mode
0800: Start unit after holiday - everything working ok. Nitrates a little high = 0.5 ppm
0830: Per Charles Schaefer we will only sample Influent and Effluent NDMA one time per week.
1455: Nitrates still 0.5 - will scrape nickel in morning & re-check.
1700: Turn off hydrogen - end of day.

EK

1-4-07 Thursday

Personnel: E. Koch

Weather: Mostly sunny, 32° - high of 50.

0700: Arrive onsite. Check nitrates - none in system. Will not scrape drum, but will ~~check~~ Monitor throughout day.

0730: Sample EFF4037-MWH for NDMA

0740: Sample INF4009-MWH for NDMA

0900: Add ~ 50 gallons into influent tank.

1700: End of day

EK

1-5-07 Friday

Personnel: E. Koch

Weather: Snowing & cold. Expecting 8-12" of snow.

0700: Arrive onsite

0730: Take readings - everything ok. Nitrates increased to 0.25.

1406: Took another flow rate. Has decreased, but weather cool - ~ 25°.

1500: Flushed filters and shut unit down for weekend.

1530: End of day

EK

1-8-07 Monday
Personnel: E. Koch
Weather: mostly sunny, high of 41°
0700: Arrive onsite
0730: Empty 100 gallons from effluent tank.
0830: Dispose of 100 gallons @ M137.
0900: Empty another 100 gallons from effluent.
1030: Dispose of 100 gallons @ M137.
1145: Turn unit on re-circ mode.
1200: Unit starts filling / treating. Nitrates = 0, Hardness = 0.
1230: Still waiting on site to plow road to pump water. Will most likely start pumping tomorrow.
1700: End of day

EK

1-9-07 Tuesday
Personnel: E. Koch
Weather: mostly sunny, high of 50°
0700: Arrive onsite
0730: Readings ok. Nitrates up to 0.25. Only 40 gallons left in influent tank.
1230: Able to get to III-2-M2 - start pumping water.
1600: Turned unit on re-circ. mode for the evening. Not enough water to run unit overnight
1700: End of day

EK

1-10-07 Wednesday
Personnel: E. Koch, M. Johnson
Weather: mostly sunny, high of 55°

0700: Arrive onsite - unit has been in re-circ. mode all night, so begin discharging to effluent tank (for 2 hrs).
0730: M. Johnson pumps ~ 50 gallons into influent tank.
0800: Set up @ well to purge
0900: Begin treatment again.
1300: Electrician works on timers, but treatment was not interrupted.
1600: M. Johnson begins pumping 150 gallons into influent tank.
1700: Turn hydrogen off for night. End of day.

EK

1-11-07 Thursday
Personnel: E. Koch, M. Johnson
Weather: Mostly sunny, 30°, turning cool w/ possible snow later.

0700: Arrive onsite
0800: Sample INF4010-MWH for NDMA.
0815: Sample EFF4038-MWH for NDMA.
0910: M. Johnson sets up @ well to purge water.
1500: Purge ~ 150 gallons into influent tank. Weather has turned much cooler. Temps are to be 0 or below for next couple days.
1700: End of day.

EK

NDMA Cycle Schedule April 2006 - May 2006

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	DO*	Influent Sample Results*	Effluent Sample Results*	Notes
Wed	4/19/2006	14:00 - 18:00	1	2hr 57min	1hr 3min	15:00	8	0				
		18:00 - 22:00	2	2hr 57min	1hr 3min							
Thur	4/20/2006	22:00 - 02:00	3	2hr 57min	1hr 3min							
		02:00 - 06:00	4	2hr 57min	1hr 3min							
		06:00 - 10:00	5	2hr 57min	1hr 3min							
		10:00 - 11:00	**X**	2hr 57min	1hr 3min							1 hour delay. Feedline to reactor blocked. Evaluated that fill port cracked.
		11:00 - 15:00	6	2hr 57min	1hr 3min	14:00	0	0	0.6	Time collected: 11:15 NDMA = 3.8 µg/L TCE = 230 µg/L cis 1,2-DCE = 4.2 µg/L VC = ND	Time collected: 14:00 NDMA = ND TCE = ND cis 1,2-DCE = ND VC = ND	
		15:00 - 19:00	7	2hr 57min	1hr 3min							
		19:00 - 23:00	8	2hr 57min	1hr 3min							
Fri	4/21/2006	23:00 - 03:00	9	2hr 57min	1hr 3min							
		03:00 - 07:00	10	2hr 57min	1hr 3min							
		07:00 - 08:00	**X**	2hr 57min	1hr 3min							1 hour delay. Feedline to reactor blocked. Evaluated and re-set system.
		08:00 - 12:00	11	2hr 57min	1hr 3min	11:05	0	0	0.15		Time collected: 11:20 NDMA = ND	
		12:00 - 12:30	**X**	2hr 57min	1hr 3min							1/2 hour delay for maintance. Sturgeon repaired electrical feedline.
		12:30 - 16:30	12	2hr 57min	1hr 3min							End of day - shut system down over weekend.
Mon	4/24/2006	08:00 - 12:00	13	2hr 57min	1hr 3min	11:30	0	0	0.5		Time collected: 11:30 NDMA = ND TCE = ND cis, 1,2-DCE = ND VC = ND	Started up unit at 8:00 am Monday morning.
		12:00 - 16:00	14	2hr 57min	1hr 3min					Time collected: 14:10 NDMA = 3.8 µg/L TCE = 220 J µg/L cis, 1,2-DCE = 3.4 µg/L VC = ND		
		16:00 - 20:00	15	2hr 57min	1hr 3min							
		20:00 - 24:00	16	2hr 57min	1hr 3min							
Tues	4/25/2006	24:00 - 04:00	17	2hr 57min	1hr 3min							
		04:00 - 08:00	18	2hr 57min	1hr 3min							
		08:00 - 12:00	19	2hr 57min	1hr 3min	11:05	0	0	0		Time collected: 11:10 NDMA = ND	
		12:00 - 16:00	20	2hr 57min	1hr 3min							
		16:00 - 20:00	21	2hr 57min	1hr 3min							
		20:00 - 24:00	22	2hr 57min	1hr 3min							
Wed	4/26/2006	24:00 - 04:00	23	2hr 57min	1hr 3min							
		04:00 - 08:00	24	2hr 57min	1hr 3min							

NDMA Cycle Schedule April 2006 - May 2006

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	DO*	Influent Sample Results*	Effluent Sample Results*	Notes
		08:00 - 12:00	25	2hr 57min	1hr 3min	11:00	0	0	0		Time collected: 11:10 NDMA = ND	
		12:00 - 18:00	26	3hr 30min	2hr 30min							
		18:00 - 24:00	27	3hr 30min	2hr 30min							
Thur	4/27/2006	24:00 - 06:00	28	3hr 30min	2hr 30min							
		06:45 - 12:45	29	3hr 30min	2hr 30min	10:45	0	0	n/a		Time collected: 10:45 NDMA = ND	45 min delay in start of the fill cycle, cause unknown. Fill cycle started @ 6:45
		12:45 - 18:45	30	3hr 30min	2hr 30min							
		18:45 - 24:45	31	3hr 30min	2hr 30min							
Fri	4/28/2006	24:45 - 07:15	32	3hr 30min	2hr 30min							30 min delay in fill cycle, cause unknown. Fill cycle started @ 7:15
		07:15 - 13:23	33	3hr 30min	2hr 30min	11:30	0	0	n/a		Time collected: 11:15 NDMA = ND	Shut unit down for weekend. Shut down at the beginning of the next fill cycle.
Mon	5/1/2006	12:00 - 20:20	34	3hr 30min	4hr 40min	16:00	0	n/a	n/a		Time collected: 15:45 NDMA = ND	Start-up at 12:05. Ajusted Timers mid cycle
		20:20 - 04:20	35	4hr 40min	3hr 00min							Ajusted Timer settings. 8 hr cycles. RTD +DET=7Hhr. 40 Min. 20 min to compansate for unexplaned addition of time during cycle. Total cycle time = 8 hrs.
Tue	5/2/2006	04:20 - 12:30	36	4hr 40min	3hr 00min	7:45	0	n/a	n/a		Time collected: 08:00 NDMA = ND	Gained 10 min. over 2 cycles. Cause unknown
		12:30 - 20:30	37	4hr 40min	3hr 00min							
Wed	5/3/2006	20:30 - 04:30	38	4hr 40min	3hr 00min							Installed water meter. Meter reading is reading 200 gallons at start.
		04:30 - 12:12	39	4hr 40min	3hr 00min	8:05	0	0	n/a	Time collected: 12:45 NDMA: = 3.1 μg/L TCE = 460 μg/L cis, 1,2-DCE = 7.5 μg/L VC = ND	Time collected: 08:10 NDMA = ND TCE = ND cis, 1,2-DCE = ND VC = ND	
		12:12 - 19:50	40	4hr 40min	3hr 00min	16:40	0	0	n/a			
Thu	5/4/2006	19:50 - 03:20	41	4hr 40min	3hr 00min							
		03:20 - 11:20	42	4hr 40min	3hr 00min	9:30	0	0	n/a		Time collected: 09:40 NDMA = ND	
		11:20 - 19:00	43	4hr 40min	3hr 00min							
Fri	5/5/2006	19:00 - 03:20	44	4hr 40min	3hr 00min							
		03:20 - 11:00	45	4hr 40min	3hr 00min	9:00	0	0	n/a		Time collected: 09:05 NDMA = ND	Fill cycle started at 11:00. Shut system down at 11:00 for weekend.
Mon	5/8/2006	n/a	n/a	n/a	n/a					N/A	N/A	Started pump @06:00 flowrates were 2 to 3 gal/min. Determined not to start up unit but to replace filters.
Tue	5/9/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit down to replace filter due to slow flow rate.
Wed	5/10/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit down to replace filter due to slow flow rate.
Thur	5/11/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit down to replace filter due to slow flow rate.
Fri	5/12/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit down for weekend
Mon	5/15/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit not running. Replaced filters.
Tues	5/16/2006	n/a	n/a	n/a	n/a					N/A	N/A	Unit not running. Replaced filters.

NDMA Cycle Schedule April 2006 - May 2006

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	DO*	Influent Sample Results*	Effluent Sample Results*	Notes
Wed	5/17/2006	n/a	n/a	n/a	n/a					N/A	N/A	Started unit at 08:00. Turned hydrogen on @ 10:00. Timers malfunctioned - system not in complete operation, but cycling w/out hydrogen.
Thur	5/18/2006	08:00 - 12:00	46	3hr	1hr	11:05	0.5	0	n/a		Time collected: 11:10 NDMA = 0.62 μg/L	Started unit at 08:00.
		12:00 - 16:00	47	3hr	1hr							
		16:00 - 20:00	48	3hr	1hr							
		20:00 - 24:00	49	3hr	1hr							
Fri	5/19/2006	24:00 - 04:00	50	3hr	1hr							
		04:00 - 08:00	51	3hr	1hr							
		08:00 - 12:00	52	3hr	1hr	11:00	2	n/a	n/a		Time collected: 11:12 NDMA = 1.6 μg/L	
		12:00 - 16:00	53	3hr	1hr							Shut down unit at 16:00 over weekend.
Mon	5/22/2006	08:00 - 12:00	54	3hr	1hr	11:00	1	0	n/a			
		12:00 - 16:00	55	3hr	1hr	15:00	1	0	0.75			
		16:00 - 20:00	56	3hr	1hr							
		20:00 - 24:00	57	3hr	1hr							
Tues	5/23/2006	24:00 - 04:00	58	3hr	1hr							
		04:00 - 08:00	59	3hr	1hr	7:15	0.5	0	1			
		08:00 - 12:00	60	3hr	1hr	7:55	2	0	1.5			
		12:00 - 16:00	61	3hr	1hr	13:00	2	0	1.5			
		16:00 - 20:00	62	3hr	1hr							
		20:00 - 24:00	63	3hr	1hr							
Wed	5/24/2006	24:00 - 04:00	64	3hr	1hr							
		04:00 - 08:00	65	3hr	1hr	7:30	2.5	0	1.75			Shut unit down at 09:30. Flushed filters. Shut down because of increasing nitrate concentration.

* Results presented in this table have been derived from field instruments, STL-Denver, and MWH Laboratories.

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
Wed	10/4/2006	07:00 - 10:00	1	1	2	--	--	--	--					
	10/4/2006	10:00 - 13:00	2	1	2						NDMA = 1.8 µg/L TCE = 410 µg/L cis, 1,2-DCE = 19 µg/L VC = ND	NDMA = 1.7 µg/L TCE = 79 µg/L cis, 1,2-DCE = 9.8 µg/L VC = ND		
	10/4/2006	13:00 - 16:00	3	1	2									
	10/4/2006	16:00 - 24:00	4	6.5	1.5									Timers may not have worked - not sure if cycle is ok
Thur	10/5/2006	24:00 - 08:00	5	6.5	1.5									Timers may not have worked - not sure if cycle is ok
	10/5/2006	08:00 - 16:00	6	6.5	1.5	11:25	3	0	8			NDMA = 2.7 µg/L		
	10/5/2006	17:00 - 01:00	7	6.5	1.5									Pressure is messing with timers - not sure what cycle or if cycle is working properly
Fri	10/6/2006	01:00 - 09:00	8	6.5	1.5	8:25	3	0	7			Nickel = 2600 µg/L		Pressure is messing with timers - not sure what cycle or if cycle is working properly
	10/6/2006													
Restarted unit on 10/9/06														
Mon	10/9/2006	16:20 - 12:20	1	6	2	16:00	2	0	7.5	1	--	--		Started timers at 16:20, 8 hour cycles.
Fri	10/6/2006	--	--	--	--	--	--	--	--	--	--	--		Shut down unit due to high nitrate readings. Hydrogen not working properly as well.
Restarted unit on 10/11/06 with original nickel														
Wed	10/11/2006	13:20 - 21:20	1	6	2									Added 800 grams of original nickel @ 13:15
Thur	10/12/2006	--	--	--	--	--	--	--	--	--	--	--		Shut down unit due to leaky pump. 10/16/06 regenerated resin in water softener. 10/24/06 installed repaired pump. 10/24/06 cracked plastic housing on pump during installation. Repaired crake housing same day with "Plast-Aid" plastic repair compound. Headspace magnahelic acting up. Headspace = 0.
Restarted unit on 10/2506 with original nickel														
Wed	10/25/2006	04:00 - 12:00	1	6	2	15:30	0.5	0	7.5	<1			177.8	Added 500gram of nickel to unit at 1400. Estimated that 40% of the 800 gram of nickel add on 10/12 remaining is system after loss of 110 gals from system do to leaky pump on 10/12/06. Valve to headspace shut off due to problems.
Thur	10/26/2006	12:00 - 08:00	2	6	2	7:05	0	0	7.5	<1				
	10/26/2006	08:00 - 16:00	3	6	2	11:30	0	n/a	n/a	<1				At 1350, 10 min. before the RTE to begin site power went down. Power still down at end of day.
Fri	10/27/2006	08:30 - 16:30	4	6	2	8:50	0.75	n/a	n/a	<1				0700 started unit up on DTE for 1.5 hr to make room for new water for cycle 4. Started cycle 4 at 830.
	10/27/2006		4	6	2	13:00	0	n/a	n/a	<1				
	10/27/2006		4	6	2	15:00	0	n/a	n/a	<1	n/a	NDMA = ND		EFF-4022 sample NDMA only collected at 1500. 30 MIN. into DTE. Shut unit down at 1630 for the weekend.
Mon	10/30/2006	08:00 - 16:00	5	6	2	10:00	0.25	0	7.5	<1		NDMA = ND Toluene = 1240 µg/L TCE = ND cis, 1,2-DCE = ND VC = ND		Restarted unit Sampled 4022 @ 14:00 - 1 hour into discharge.

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
	10/30/2006	16:00 - 12:00	6	6	2									
Tues	10/31/2006	12:00 - 08:00	7	6	2	6:45	0	0	8	<1				
		08:00 - 14:00	8	4	2	1210	0	n/a	n/a	<1				
		14:00 - 20:00	9	4	2									
		20:00 - 02:00	10	4	2									
Wed	11/1/2006	02:00 - 08:00	11	4	2	7:40	0	0	8	<1		NDMA = ND		Sampled 4023 1.5 hours into discharge.
		08:00 - 14:00	12	4	2								198.7	
		14:00 - 20:00	13	4	2									
Thur	11/2/2006	20:00 - 02:00	14	4	2									
		02:00 - 08:00	15	4	2	7:55	0	160	8	<1				
		08:00 - 14:00	16	4	2	13:00	0	180	7.5	<1				Hardness = 0 from water softener
		14:00 - 20:00	17	4	2									
Fri	11/3/2006	20:00 - 02:00	18	4	2									
		02:00 - 08:00	19	4	2	7:30	0	100	8	<1		NDMA = ND		Elevated Hardness reading = 100ppm from effluent and 40ppm from water softener.
		08:00 - 14:00	20	4	2	12:45	0	80	8	<1			209.2	14:00 - Shut unit down for weekend. Attempted to regenerated water softener. Softener regeneration failed. Reason unknown.
Mon	11/6/2006	16:00 - 22:00	21	4	2									Dismantled and cleaned unit. Connected unit to higher PSI pump and regenerated water softener. Regeneration was successful. Started unit @ 1600
Tues	11/7/2006	22:00 - 04:00	22	4	2									
		04:00 - 10:00	23	4	2	7:30	0	0	7.5	<1				
		10:00 -14:00	24	3	1	11:30	0.25	0	8	<1				Short cycle to reset schedule to more convenient sample times.
		14:00 - 20:00	25	4	2									
Wed	11/8/2006	20:00 - 02:00	26	4	2									
		02:00 - 08:00	27	4	2	7:15	0	0	7.5	<1				
		08:00 - 14:00	28	4	2	11:40	0	n/a	n/a	n/a		NDMA = ND TCE = 0.3 J μg/L cis, 1,2-DCE = ND VC = ND		13:00 sampled NDMA EFF4025. 1 hour into drain cycle
		14:00 - 20:00	29	4	2	15:35	0.25	n/a	n/a	n/a				
Thur	11/9/2006	20:00 - 02:00	30	4	2									
		02:00 - 08:00	31	4	2	7:05	0	0	8	<1			221.9	
		08:00 - 14:00	32	4	2	12:00	0	n/a	n/a	n/a				
		14:00 - 20:00	33	4	2	15:15	0	n/a	n/a	n/a				
Fri	11/10/2006	20:00 - 02:00	34	4	2									
		02:00 - 08:00	35	4	2	8:00	0	0	8	<1			231	
		08:00 - 14:00	36	4	2	11:20	0	n/a	n/a	n/a		NDMA = 0.0058 μg/L		1300 - collected NDMA sample EFF-4026, to MWH. 1400 shut unit down for the weekend

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
Mon	11/13/2006	08:0 - 14:00	37	4	2	8:05	0.25	0	7.5	<1	NDMA = 2.6 mg/L TCE - 550 µg/L cis, 1,2-DCE = 20 µg/L VC = 2 µg/L			collected influent sample Inf- 4020 @ 0900
						11:15	0	n/a	n/a	n/a				
		14:00 - 20:00	38	4	2	14:30	0	n/a	n/a	n/a				
		20:00 - 02:00	39	4	2									
Tue	11/14/2006	02:00 - 08:00	40	4	2	7:30	0	0	7.5	<1		NDMA = 0044 µg/L	242.9	0715 collected NDMA sample to MWH - EFF4027
		08:00 - 14:00	41	3.5	2.5	12:00	0	n/a	n/a	n/a				
		14:00 - 20:00	42	3.5	2.5									
		20:00 - 02:00	43	3.5	2.5									
Wed	11/15/2006	02:00 - 08:00	44	3.5	2.5									
		08:00 - 14:00	45	3.5	2.5	8:10	0.25	0	7.5	n/a				
						11:15	0	n/a	n/a	<1			250.6	
		14:00 - 20:00	46	3.5	2.5									
		20:00 - 02:00	47	3.5	2.5									
Thur	11/16/2006	02:00 - 08:00	48	3.5	2.5	7:50	0	0	7.5	<1				
		08:00 - 14:00	49	3.5	2.5							NDMA = ND TCE = 0.3 F µg/L cis,1,2-DCE = ND VC = ND		12:00 collected EFF4025 for STL - full suite - and EFF4028-MWH for MWH lab - NDMA only
		14:00 - 20:00	50	3.5	2.5									
		20:00 - 02:00	51	3.5	2.5									
Fri	11/17/2006	02:00 - 08:00	52	3.5	2.5									
		08:00 - 14:00	53	3.5	2.5	8:00	0	0	8	<1			261.4	shut down unit at 14:00 for the weekend. Removed the "B" filter and attempted to push foam balls through the filter with a sump pump. Pump did not have enough PSI. test failed.
Mon	11/20/2006	08:00 - 14:00	54	3.5	2.5	8:10	0	10	7	<1				
		14:00 - 18:00	55	2	2	12:20	0	n/a	n/a	n/a				
						16:00	n/a	0	n/a	n/a				
		18:00 - 22:00	56	2	2									
Tue	11/21/2006	22:00 - 02:00	57	2	2									
		02:00 - 06:00	58	2	2									
		06:00 - 10:00	59	2	2	7:45	0.1	0	7.5	<1				
		10:00 - 14:00	60	2	2	13:00	0	n/a	n/a	n/a		NDMA = 0.0041 µg/L Toluene = 349 µg/L TCE = ND cis, 1,2-DCE = ND ND = ND		Sampled EFF4029-MWH @ 13:05 for NDMA and VOC.
		14:00 - 18:00	61	2	2									
		18:00 - 22:00	62	2	2									
Wed	11/22/2006	22:00 - 02:00	63	2	2									
		02:00 - 06:00	64	2	2									
		06:00 - 10:00	65	2	2	8:00	0.1	0	8	<1			275	

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
		10:00 - 14:00	66	2	2	11:00	0.4	n/a	n/a	n/a				Shut unit down @ 14:00 for holiday weekend. 1500 completed regeneration of water softener. 1600 removed filter "B" and pushed 4 foam balls through the filter 3 separate times. Then re-installed the filter.
Mon	11/27/2006	09:00 - 13:00	67	2	2	9:10	0.35	0	7.5	<1				First flow measurements indicate that the flow rate from "B" filter increase by a factor of X2 after cleaning filter using foam balls. Elevated nitrate reading
		13:00 - 17:00	68	2	2	15:05	0.5	n/a	n/a	n/a				Nitrate levels were elevated on field strips. Removed lid on reactor and scraped nickel buildup on top of ring (holding the tubing) and side of drum. Not sure if elevated reading were do to very cold weather and operating temperature or nickel settling on ring. Nickel looks deep gray in color and there was a buildup of nickel on many plastic surfaces.
		17:00 - 21:00	69	2	2	16.3	0.5	n/a	n/a	n/a				
		21:00 - 01:00	70	2	2									
Tue	11/28/2006	01:00 - 05:00	71	2	2									
		05:00 - 09:00	72	2	2	7:05	0	0	8	<1			292.2	Nitrate levels are normal.
		09:00 - 13:00	73	2	2	11:05	0	n/a	n/a	n/a		NDMA = 0.0026 µg/L TCE = 2 µg/L cis 1,2-DCE = 2 µg/L VC = 2 µg/L		Sampled EFF4030 full VOC suite for STL: **NDMA to MWH**.
		13:00 - 17:00	74	2	2	1515	0.25	n/a	n/a	n/a				
		17:00 - 23:00	75	4	2									Cold Front hitting tonight. Lows of 8 and highs 25 expected. Changed cycle time so we will no run out of water. Water collection will be dependent on weather. Unit needs to be keep running to avoid freezing.
	11/28/2006	23:00 - 05:00	76	4	2									
Wed	11/29/2006	05:00 - 11:00	77	4	2	8:05	0.25	0	8	<1				Currently snowing, high of only 18 expected. Ground water was collected today.
	11/29/2006	11:00 - 17:00	78	4	2	13:23	0	n/a	n/a	n/a				
		17:00 - 23:00	79	4	2	15:50	0	n/a	n/a	n/a				
Thur	11/30/2006	23:00 - 05:00	80	4	2									
		05:00 - 11:00	81	4	2	7:50	0.25	0	8	<1				
						9:15	0	n/a	n/a	n/a		NDMA = ND		Collected NDMA @ 09:15 EFF-4031-MWH
		11:00 - 17:00	82	4	2	15:30	0	n/a	n/a	n/a			304.9	
		17:00 - 23:00	83	4	2									
Fri	12/1/2006	23:00 - 05:00	84	4	2									
		05:00 - 11:00	85	4	2	7:18	0.25	0	8	<1				
		11:00 - 17:00	86	4	2	12:10	0.5	n/a	n/a	n/a				Collected DO from influent = 5.4 ppm
						15:02	0.5	n/a	n/a	n/a				Flushed filters at 17:00 and shut unit down for weekend.
Mon	12/4/2006	08:00 - 14:00	87	4	2	8:15	0.25	0	7.5	<1			317.97	07:20 turn pump on circulation mode. At 08:00 turn on hydrogen and start timers.
		14:00 - 20:00	88	4	2									
Tues	12/5/2006	20:00 - 02:00	89	4	2									

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
		02:00 - 08:00	90	4	2	7:10	0	0	8	<1				At 07:45 re-adjusted timers - a little off - to start again at 08:00.
		08:00 - 14:00	91	4	2	13:03	0	n/a	n/a	n/a				
		14:00 - 20:00	92	4	2									
Wed	12/6/2006	20:00 - 02:00	93	4	2									
		02:00 - 08:00	94	4	2	7:05	0.25	0	8	<1		NDMA = 0.016 µg/L Nickel = 340 µg/L	329.3	At 07:00 T. Rulon added 100 psi to tank. Sampled EFF4034 @ 07:10 Diss. Metals, Total metals for STL and EFF4034-MWH for NDMA
		08:00 - 14:00	95	4	2	12:52	0.25	n/a	n/a	n/a				
		14:00 - 20:00	96	4	2	16:05	0.5	n/a	n/a	n/a				
Thur	12/7/2006	20:00 - 02:00	97	4	2									
	12/7/2006	02:00 - 08:00	98	4	2	7:10	0.5	0	8	<1				07:00 turned hydrogen on - system ok. Weather cool, 19˚, high of 40˚ today.
	12/7/2006	08:00 - 14:00	99	4	2									
	12/7/2006	14:00 - 20:00	100	4	2									
Fri	12/8/2006	20:00 - 02:00	101	4	2									
	12/8/2006	02:00 - 08:00	102	4	2	7:10	0.25	0	8	<1			342.2	
	12/8/2006	08:00 - 14:00	103	4	2	12:00	0.25	n/a	n/a	n/a				Regenerated water softener @10:45. Shut unit down at 14:00 for weekend. At 14:30 flushed filters and ran four blue foam balls through filter "B" three separate times. Re-installed filter.
Mon	12/11/2006	08:30 - 14:30	104	4	2	8:28	0	0	8	<1				Started unit up @ 07:30 - purged air out of system. Treatment began at 08:30. Scraped nickel off sides of drum to make it more agitated.
		14:30 - 20:30	105	4	2									
Tues	12/12/2006	20:30 - 02:30	106	4	2									
		02:30 - 08:00	107	4	2	7:05	0	0	8	<1			365.9	
		08:00 - 14:00	108	4	2	2:05	1	n/a	n/a	n/a				Re-adjusted timer to start at 08:00.
		14:00 - 20:00	109	4	2	4:15	0.5	n/a	n/a	n/a				Nitrates dropped from 1 at beginning of cycle to .5 two hrs. into cycle
Wed	12/13/2006	20:30 - 02:30	110	4	2	7:05	0.5	0	8	<1				Nitrates were .5 @ 0700
		02:30 - 08:00	111	4	2									
		08:00 - 14:00	112	4	2	n/a	n/a	n/a	n/a	n/a				Changed hydrogen canister. Scraped nickel off side of drum and rim of tubing rack. Let system run without collecting measurements.
		14:00 - 20:00	113	4	2	16:00	0.5	0	8	<1				Nitrates still 1 @1600
Thur	12/14/2006	20:30 - 02:30	114	4	2									
		02:30 - 08:00	115	4	2									
		08:00 - 14:00	116	4	2	7:20	0-.1	0	8.5	<1			+	Nitrates seem to have decreased. TR increased hydrogen pressure on gauge PI-205
		14:00 - 20:00	117	4	2	14:08	0	n/a	n/a	n/a				
Fri.	12/15/2006	20:30 - 02:30	118	4	2									
		02:30 - 08:00	119	4	2	7:15	0	0	8	<1				
		08:00 - 14:00	120	4	2							NDMA = 0.002	389.0	Flushed filters at 12:00 and shut down system for weekend.

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
Mon	12/18/006	08:30 - 14:30	121	4	2	8:35	0	0	8	<1				Turned unit on in re-circulation mode @ 0730. Turned hydrogen and system on for treatment on @ 08:30.
		14:30 - 20:30	122	4	2	14:54	0.25	n/a	n/a	n/a				Nitrates up to .25 in first two hours of cycle of 121
		20:30 - 02:30	123	4	2	16:15	0.25	n/a	n/a	n/a				
Tue	12/19/2006	02:30 - 08:30	124	4	2	7:18	0.5	0	8	<1				Timers may have re-adjusted overnight - will let it drain and re-set @ 10:00
		10:00 - 16:00	125	4	0:00	13:50	0.25	n/a	n/a	n/a				Scraped nickel off sides of drum to become more agitated.
		16:00 - 22:00	126	4	2									
Wed	12/20/2006	22:00 - 04:00	127	4	2									
		04:00 - 10:00	128	4	2	8:15	0.25	0	8	<1		NDMA = ND Nickel = 350 μg/L		Snow storm hitting - high of only 25. Flushed filters and shut system down for holiday. Blizzard conditions - will not resume Thursday. Sampled INF4008 and EFF4036.
Restarted unit on 1/03/07 after holiday														
Wed	1/3/2007	08:00 - 14:00	129	4	2	8:00	0.5	0	7.5	<1				Turned unit on in re-circulation mode @ 07:45. Turned hydrogen and system on for treatment on @ 08:00 after holiday. ~ 2-3' of snow still on ground - will not pump well until next week.
		14:00 - 20:00	130	4	2	14:55	0.5	0	7.5	<1				Nitrates still high - will scrape nickel in morning and re-check.
Thur	1/4/2007	20:00 - 02:00	131	4	2									
		02:00 - 08:00	132	4	2	7:18	0	0	7.5	<1	NDMA = 2.8 μg/L	NDMA = 0.0021 μg/L		Nitrates zero - will not scrape drum, but will monitor levels throughout day.
		08:00 - 14:00	133	4	2									
		15:00 - 21:00	134	4	2	16:00	0.25	0	7.5	<1				One hour delay - electrician working on system. Had to remove timers.
Fri	1/5/2007	21:00 - 03:00	135	4	2									
		03:00 - 09:00	136	4	2	7:35	0.25	0	8	<1				Snowing again - expecting another 12 - 16", ~ 25 degrees.
		09:00 - 15:00	137	4	2	14:06	0.25	n/a	n/a	n/a				Flushed filters @ 15:00 and shut unit down for weekend.
Mon	1/8/2007	12:00 - 18:00	138	4	2	12:02	0	0	8	<1			410.4	Turned unit on recirc. @ 11:45 - began filling/treating @ 12:00. Still waiting on ok to get to well to pump water.
		18:00 - 24:00	139	4	2									
Tues	1/9/2007	24:00 - 06:00	140	4	2									
		06:00 - 12:00	141	4	2	7:30	0.25	0	8	<1				
		12:00 - 16:00	142	4	2	16:00	0.25	n/a	n/a	n/a				Low on water in influent tank - will put unit into re-circ mode until Wed. morning and restart treatment.
Wed	1/10/2007	16:00 - 09:00	142	--	--	8:05	0	0	8	<1				Unit has been re-circulating all night. Let unit discharge to effluent tank from 07:00 - 09:00.
		09:00 - 15:00	143	4	2									Started treatment @ 09:00.
		15:00 - 21:00	144	4	2	15:22	0.25	n/a	n/a	n/a				
Thur	1/11/2007	21:00 - 03:00	145	4	2									
		03:00 - 09:00	146	4	2	8:05	0.25	0	8	<1	NDMA = 3.1 μg/L	NDMA = 0.233 μg/L		Sampled Influent @ 08:00 and Effluent @ 08:15
		09:00 - 15:00	147	4	2									Cold front coming in, temperatures expected to drop to below freezing.
		15:00 - 21:00	148	4	2									
Fri	1/12/2007	21:00 - 03:00	149	4	2									

NDMA Cycle Schedule October 2006 - January 2007

Day	Date	Schedule	Cycle #	Return to Drum (time)	Return to Effluent (time)	Time	Nitrate*	Hardness*	pH*	DO*	Influent Samples	Effluent Samples	Water Meter Reading	Notes
		03:00 - 09:00	150	4	2	8:00	0.25	0	8	<1				Temperature at 0 degrees this morning. Unit had ambient temp of 50 and recirc temp was 85.
		09:00 - 12:00	--			11:35	0.25	n/a	n/a	n/a				Let unit drain down from 09:00 - 12:00. Flushed filters @ 12:05 and scraped nickel from sides of drum. Shut unit down for weekend.

* Results presented in this table have been derived from field instruments, STL-Denver, and MWH Laboratories.

APPENDIX D

RACER ESTIMATES

TABLE D-1
ALTERNATIVE 1
NO ACTION
COST SUMMARY

Task	Totals
Capital Costs	
No Capital Costs	$0
Total Capital Costs	**$0**
Periodic Costs (30-year):	
5-Year Reviews (year 5-30)	$66,168
Total Periodic Costs	**$66,168**
TOTAL PRESENT WORTH	**$24,000**

TABLE D-2
ALTERNATIVE 1
NO ACTION
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals
Capital Costs:					
No Direct Capital Costs				$0	
Total Capital Costs					**$0**
Periodic Costs (30-year):					
5-year Review					
Site Inspection	event	1	$2,462	$2,462	
Report	ea	1	$8,566	$8,566	
				5-year Review year 5-30 Total	$11,028
				5-year Review year 5-30 Total	**$66,168**
Total Periodic Costs					**$66,168**

TABLE D-2
ALTERNATIVE 1
NO ACTION
COST BREAKDOWN DETAILS

PRESENT WORTH ANALYSIS					
Year	**Capital Costs**	**Periodic Costs**	**Total Annual Expenditure**	**Discount Factor (7%)**	**Present Worth**
0	0		$0	1.0000	**$0**
1	$0		$0	0.9346	**$0**
2	$0		$0	0.8734	**$0**
3	$0		$0	0.8163	**$0**
4	$0		$0	0.7629	**$0**
5	$0	$11,028	$11,028	0.7130	**$7,863**
6	$0		$0	0.6663	**$0**
7	$0		$0	0.6227	**$0**
8	$0		$0	0.5820	**$0**
9	$0		$0	0.5439	**$0**
10	$0	$11,028	$11,028	0.5083	**$5,606**
11	$0		$0	0.4751	**$0**
12	$0		$0	0.4440	**$0**
13	$0		$0	0.4150	**$0**
14	$0		$0	0.3878	**$0**
15	$0	$11,028	$11,028	0.3624	**$3,997**
16	$0		$0	0.3387	**$0**
17	$0		$0	0.3166	**$0**
18	$0		$0	0.2959	**$0**
19	$0		$0	0.2765	**$0**
20	$0	$11,028	$11,028	0.2584	**$2,850**
21	$0		$0	0.2415	**$0**
22	$0		$0	0.2257	**$0**
23	$0		$0	0.2109	**$0**
24	$0		$0	0.1971	**$0**
25	$0	$11,028	$11,028	0.1842	**$2,032**
26	$0		$0	0.1722	**$0**
27	$0		$0	0.1609	**$0**
28	$0		$0	0.1504	**$0**
29	$0		$0	0.1406	**$0**
30	$0	$11,028	$11,028	0.1314	**$1,449**
TOTAL PRESENT WORTH					**$24,000**

TABLE D-3
ALTERNATIVE 2
IN SITU BIOREMEDIATION AND ENVIRONMENTAL COVENANT
COST SUMMARY

Task	Totals
Capital Costs:	
Well abandonment - Lariat Gulch (year 30)	$416,579
Well abandonment - Horizontal (year 30)	$28,167
Well abandonment - Remaining wells (year 30)	$278,399
Final Round of Injections	$344,208
Total Capital Costs	**$1,067,353**
Periodic Costs (30-year):	
5-year Review (year 5-30)	$103,458
Groundwater Monitoring (year 0-5)	$320,578
Groundwater Monitoring (year 6-30)	$776,703
Environmental Covenant (year 1-30)	$81,300
Total Periodic Costs (for 30 years)	**$1,282,039**
TOTAL PRESENT WORTH	**$611,000**

TABLE D-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION AND ENVIRONMENTAL COVENANT
COST BREAKDOWN DETAILS

Task	Unit	Quantity	Unit Cost	Subtotals	Totals	Comments
Capital Costs:						
Well Abandonment - Lariat Gulch	event	1	$416,579	$416,579		10 deep wells (~500') abandonment
Well Abandonment - Horizontal	event	1	$28,167	$28,167		10 horizontal wells (~500') abandonment
Well Abandonment - Remaining	event	1	$278,399	$278,399		350 wells, average depth of 70', abandonment
Final Round of Injections	event	1	$344,208	$344,208		EEO Injections at 32 vertical wells, 10 horizontal
Total Capital Costs					**$1,067,353**	
Periodic Costs:						
5-Year Review (year 5-30)						
Document Review	ea	1	$6,215	$6,215		
Site Inspection	event	1	$2,462	$2,462		
Report	ea	1	$8,566	$8,566		
Yearly Subtotal				$17,243		
				5-year Review Subtotal	**$17,243**	
				5-year Review year 5-30 Total	**$103,458**	
Groundwater Monitoring (year 0-5)						
Groundwater	event	1	$35,556	$35,556		50 wells monitored for VOCs, NDMA - first year includes monitoring plan
Data Management	event	1	$11,095	$11,095		Abbreviated reporting, stage 1 data review
General Monitoring	event	1	$2,470	$2,470		Sample management and shipping
Yearly Subtotal				$49,121		
				Groundwater Monitoring (one year) Subtotal	**$49,121**	
				Groundwater Monitoring year 0-5 Total	**$320,578**	
Groundwater Monitoring (year 6-30)						
Groundwater	event	1	$19,818	$19,818		50 wells monitored for VOCs, NDMA - first year includes monitoring plan
Data Management	event	1	$7,597	$7,597		Abbreviated reporting, stage 1 data review
General Monitoring	event	1	$1,918	$1,918		Sample management and shipping
Yearly Subtotal				$29,333		
				Groundwater Monitoring (one year) Subtotal	**$29,333**	
				Groundwater Monitoring year 6-30 Total	**$776,703**	
Environmental Covenant (year 1-30)						
Monitoring and Enforcement	ea	1	$2,710	$2,710		One day site walk annually
Yearly Subtotal				$2,710		
				Environmental Covenant (one year) Subtotal	**$2,710**	
				Environmental Covenant year 6-30 Total	**$81,300**	
Total Periodic Costs					**$1,282,039**	

TABLE D-4
ALTERNATIVE 2
IN SITU BIOREMEDIATION AND ENVIRONMENTAL COVENANT
COST BREAKDOWN DETAILS

PRESENT WORTH ANALYSIS					
Year	Capital Costs	Periodic Costs	Total Annual Expenditure	Discount Factor (7%)	Present Worth
0	$1,067,353	$49,121	$1,116,474	1.0000	$1,116,474
1	$0	$51,831	$51,831	0.9346	$48,440
2	$0	$51,831	$51,831	0.8734	$45,271
3	$0	$51,831	$51,831	0.8163	$42,310
4	$0	$51,831	$51,831	0.7629	$39,542
5	$0	$69,074	$69,074	0.7130	$49,249
6	$0	$32,043	$32,043	0.6663	$21,352
7	$0	$32,043	$32,043	0.6227	$19,955
8	$0	$32,043	$32,043	0.5820	$18,649
9	$0	$32,043	$32,043	0.5439	$17,429
10	$0	$49,286	$49,286	0.5083	$25,055
11	$0	$32,043	$32,043	0.4751	$15,223
12	$0	$32,043	$32,043	0.4440	$14,227
13	$0	$32,043	$32,043	0.4150	$13,297
14	$0	$32,043	$32,043	0.3878	$12,427
15	$0	$49,286	$49,286	0.3624	$17,864
16	$0	$32,043	$32,043	0.3387	$10,854
17	$0	$32,043	$32,043	0.3166	$10,144
18	$0	$32,043	$32,043	0.2959	$9,480
19	$0	$32,043	$32,043	0.2765	$8,860
20	$0	$49,286	$49,286	0.2584	$12,736
21	$0	$32,043	$32,043	0.2415	$7,739
22	$0	$32,043	$32,043	0.2257	$7,233
23	$0	$32,043	$32,043	0.2109	$6,759
24	$0	$32,043	$32,043	0.1971	$6,317
25	$0	$49,286	$49,286	0.1842	$9,081
26	$0	$32,043	$32,043	0.1722	$5,518
27	$0	$32,043	$32,043	0.1609	$5,157
28	$0	$32,043	$32,043	0.1504	$4,819
29	$0	$32,043	$32,043	0.1406	$4,504
30	$723,145	$49,286	$772,431	0.1314	$101,472
TOTAL PRESENT WORTH					**$611,000**

RACER Estimates

Technology Cost Over Time Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location

State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options

Database: Modified System

Cost Database Date: 2010

Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Cost Over Time Report
(with Markups)

Site:

Site ID: Alternative 1
Site Name: No Action
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: None
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 1, No Action for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Cost Over Time Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237

Telephone Number: 720-554-8150

Email Address: lindsay.archibald@shawgrp.com

Estimate Prepared Date: 06/01/2010

Estimator Signature: ____________________ **Date:** __________

Reviewer Information

Reviewer Name: Thomas Cooper

Reviewer Title: Project Manager

Agency/Org./Office: Shaw

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237

Telephone Number: 720-554-8163

Email Address: thomas.cooper@shawgrp.com

Date Reviewed: 06/01/2010

Reviewer Signature: ____________________ **Date:** __________

Technology Cost Over Time Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for Alternative 1, No Action and only includes costs for 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
Five-Year Review	Yes	100	0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2015	2016	2017	2018	2019	2020
Site Inspection	$2,462	$0	$0	$0	$0	$2,462
Report	$8,566	$0	$0	$0	$0	$8,566
Total Technology Cost	$11,029	$0	$0	$0	$0	$11,029

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2021	2022	2023	2024	2025	2026
Site Inspection	$0	$0	$0	$0	$2,462	$0
Report	$0	$0	$0	$0	$8,566	$0
Total Technology Cost	$0	$0	$0	$0	$11,029	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2027	2028	2029	2030	2031	2032
Site Inspection	$0	$0	$0	$2,462	$0	$0
Report	$0	$0	$0	$8,566	$0	$0
Total Technology Cost	$0	$0	$0	$11,029	$0	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2033	2034	2035	2036	2037	2038
Site Inspection	$0	$0	$2,462	$0	$0	$0
Report	$0	$0	$8,566	$0	$0	$0
Total Technology Cost	$0	$0	$11,029	$0	$0	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2039	2040	Total
Site Inspection	$0	$2,462	$14,772
Report	$0	$8,566	$51,399
Total Technology Cost	$0	$11,029	$66,171

Estimate Documentation Report

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location

State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options

Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Estimate Documentation Report

Site Documentation:

Site ID: Alternative 1
Site Name: No Action
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: None
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 1, No Action for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/01/2010

Estimator Signature: ______________________ **Date:** ____________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw

Estimate Documentation Report

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com

Date Reviewed: 06/01/2010

Reviewer Signature: ______________________ **Date:** ____________

Estimated Costs:

Phase Names		Direct Cost	Marked-up Cost
LTM		$23,792	$66,171
	Total Cost:	$23,792	$66,171

Estimate Documentation Report

Phase Documentation:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for Alternative 1, No Action and only includes costs for 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
Five-Year Review	Yes	100	0

Total Marked-up Cost: $66,171

Technologies:

Estimate Documentation Report

Technology Name: **Five-Year Review (# 1)**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Site Complexity		Low	n/a
Document Review		No	n/a
Interviews		No	n/a
Site Inspection		Yes	n/a
Report		Yes	n/a
Travel		No	n/a
Rebound Study		No	n/a
Start Date		June-2015	n/a
No. Reviews		6	EA
Site Inspection			
Required Parameters			
General Site Inspection		Yes	n/a
Containment System Inspection		No	n/a
Monitoring Systems Inspection		No	n/a
Treatment Systems Inspection		No	n/a
Regulatory Compliance		Yes	n/a
Site Visit Documentation (Photos, Diagrams, etc.)		Yes	n/a
Report			
Required Parameters			
Introduction		Yes	n/a
Remedial Objectives		Yes	n/a
ARARs Review		Yes	n/a
Summary of Site Visit		Yes	n/a
Areas of Non Compliance		Yes	n/a
Technology Recommendations		Yes	n/a
Statement of Protectiveness		Yes	n/a
Next Review		Yes	n/a
Implementation Requirements		Yes	n/a

Comments:

Technology Detail Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Detail Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Detail Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237

Telephone Number: 720-554-8150

Email Address: lindsay.archibald@shawgrp.com

Estimate Prepared Date: 06/15/2010

Estimator Signature: ______________________ **Date:** __________

Reviewer Information

Reviewer Name: Thomas Cooper

Reviewer Title: Project Manager

Agency/Org./Office: Shaw

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237

Telephone Number: 720-554-8163

Email Address: thomas.cooper@shawgrp.com

Date Reviewed: 06/15/2010

Reviewer Signature: ______________________ **Date:** __________

Technology Detail Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews and well abandonment.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0

Technology Detail Report
(with Markups)

Technology:

Name: Well Abandonment
Prime Markup: 100 %
Sub Markup: 0 %

Assembly	Description	Quantity	Unit of Measure	Material Unit Cost	Labor Unit Cost	Equipment Unit Cost	SubBid Unit Cost	Extended Cost	Cost Override	Markups Applied
33010101	Mobilize/DeMobilize Drilling Rig & Crew	1.00	LS	0.00	1,822.47	1,066.55	0.00	$2,889.01	☐	☑
33220112	Field Technician	552.00	HR	0.00	106.04	0.00	0.00	$58,533.58	☐	☑
33231104	Hollow Stem Auger, 11" Dia Borehole, Depth > 100 ft	5,000.00	LF	0.00	25.07	41.81	0.00	$334,405.83	☐	☑
33231178	Move Rig/Equipment Around Site	10.00	EA	113.74	261.98	153.32	0.00	$5,290.32	☐	☑
33231820	Grout Continuous Borehole	1,734.00	CF	8.92	0.00	0.00	0.00	$15,460.47	☐	☑

Total Technology Cost **$416,579.21**

Technology Detail Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location

State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options

Database: Modified System

Cost Database Date: 2010

Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Detail Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Detail Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/15/2010

Estimator Signature: ______________________ **Date:** ____________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/15/2010

Reviewer Signature: ______________________ **Date:** ____________

Technology Detail Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews and well abandonment.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0

Technology Detail Report
(with Markups)

Technology:

Name: Well Abandonment
Prime Markup: 100 %
Sub Markup: 0 %

Assembly	Description	Quantity	Unit of Measure	Material Unit Cost	Labor Unit Cost	Equipment Unit Cost	SubBid Unit Cost	Extended Cost	Cost Override	Markups Applied
33010101	Mobilize/DeMobilize Drilling Rig & Crew	1.00	LS	0.00	1,822.47	1,066.55	0.00	$2,889.01	☐	☑
33220112	Field Technician	152.00	HR	0.00	106.04	0.00	0.00	$16,117.94	☐	☑
33231178	Move Rig/Equipment Around Site	10.00	EA	113.74	261.98	153.32	0.00	$5,290.32	☐	☑
33231820	Grout Continuous Borehole	434.00	CF	8.92	0.00	0.00	0.00	$3,869.58	☐	☑

Total Technology Cost **$28,166.85**

Technology Detail Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Detail Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Detail Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/15/2010

Estimator Signature: ______________________ **Date:** __________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/15/2010

Reviewer Signature: ______________________ **Date:** __________

Technology Detail Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews and well abandonment.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0

Technology Detail Report
(with Markups)

Technology:

Name: Well Abandonment
Prime Markup: 100 %
Sub Markup: 0 %

Assembly	Description	Quantity	Unit of Measure	Material Unit Cost	Labor Unit Cost	Equipment Unit Cost	SubBid Unit Cost	Extended Cost	Cost Override	Markups Applied
33010101	Mobilize/DeMobilize Drilling Rig & Crew	1.00	LS	0.00	1,822.47	1,066.55	0.00	$2,889.01	☐	☑
33220112	Field Technician	680.00	HR	0.00	106.04	0.00	0.00	$72,106.58	☐	☑
33231178	Move Rig/Equipment Around Site	350.00	EA	113.74	261.98	153.32	0.00	$185,161.19	☐	☑
33231820	Grout Continuous Borehole	2,046.00	CF	8.92	0.00	0.00	0.00	$18,242.29	☐	☑

Total Technology Cost **$278,399.07**

Technology Detail Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location

State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options

Database: Modified System

Cost Database Date: 2010

Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Detail Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Detail Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/01/2010

Estimator Signature: ______________________ **Date:** ____________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/01/2010

Reviewer Signature: ______________________ **Date:** ____________

Technology Detail Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING	Yes	100	0
Five-Year Review	Yes	100	0
ADMINISTRATIVE LAND USE CONTROLS	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING	Yes	100	0

Technology Detail Report
(with Markups)

Technology:

Name: FINAL ROUND OF INJECTIONS
Prime Markup: 100 %
Sub Markup: 0 %
Comments: This estimate accounts for the injection of EEO into 32 vertical wells and 10 horizontal wells.

Assembly	Description	Quantity	Unit of Measure	Material Unit Cost	Labor Unit Cost	Equipment Unit Cost	SubBid Unit Cost	Extended Cost	Cost Override	Markups Applied
33010109	Truck, 2 Axle, Highway, 21,700 GVW, 4 x 2, 2 Axle	60.00	DAY	0.00	0.00	388.81	0.00	$23,328.41	☐	☑
33190149	Truck Driver, Light	600.00	HR	0.00	92.80	0.00	0.00	$55,679.46	☐	☑
33220105	Project Engineer	100.00	HR	0.00	157.36	0.00	0.00	$15,736.14	☐	☑
33220109	Staff Scientist	1,000.00	HR	0.00	102.32	0.00	0.00	$102,321.25	☐	☑
33220112	Field Technician	1,000.00	HR	0.00	106.04	0.00	0.00	$106,039.09	☐	☑
33330184	Emulsified Vegetable Oil Bioremediation Substrate	13,000.00	LB	3.16	0.00	0.00	0.00	$41,103.86	☐	☑

Total Technology Cost **$344,208.20**

Technology Cost Over Time Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Cost Over Time Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Cost Over Time Report
(with Markups)

Business Address:	7604 Technology Way Suite 300 Denver, CO 80237
Telephone Number:	720-554-8150
Email Address:	lindsay.archibald@shawgrp.com
Estimate Prepared Date:	06/01/2010

Estimator Signature: ______________________ **Date:** ____________

Reviewer Information

Reviewer Name:	Thomas Cooper
Reviewer Title:	Project Manager
Agency/Org./Office:	Shaw
Business Address:	7604 Technology Way Suite 300 Denver, CO 80237
Telephone Number:	720-554-8163
Email Address:	thomas.cooper@shawgrp.com
Date Reviewed:	06/01/2010

Reviewer Signature: ______________________ **Date:** ____________

Technology Cost Over Time Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2015	2016	2017	2018	2019	2020
Document Review	$6,215	$0	$0	$0	$0	$6,215
Site Inspection	$2,462	$0	$0	$0	$0	$2,462
Report	$8,566	$0	$0	$0	$0	$8,566
Total Technology Cost	$17,243	$0	$0	$0	$0	$17,243

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2021	2022	2023	2024	2025	2026
Document Review	$0	$0	$0	$0	$6,215	$0
Site Inspection	$0	$0	$0	$0	$2,462	$0
Report	$0	$0	$0	$0	$8,566	$0
Total Technology Cost	$0	$0	$0	$0	$17,243	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2027	2028	2029	2030	2031	2032
Document Review	$0	$0	$0	$6,215	$0	$0
Site Inspection	$0	$0	$0	$2,462	$0	$0
Report	$0	$0	$0	$8,566	$0	$0
Total Technology Cost	$0	$0	$0	$17,243	$0	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2033	2034	2035	2036	2037	2038
Document Review	$0	$0	$6,215	$0	$0	$0
Site Inspection	$0	$0	$2,462	$0	$0	$0
Report	$0	$0	$8,566	$0	$0	$0
Total Technology Cost	$0	$0	$17,243	$0	$0	$0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Five-Year Review
Prime Markup: 100 %
Sub Markup: 0 %

	2039	2040	Total
Document Review	$0	$6,215	$37,288
Site Inspection	$0	$2,462	$14,772
Report	$0	$8,566	$51,399
Total Technology Cost	$0	$17,243	$103,459

Technology Cost Over Time Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Cost Over Time Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type
Primary: Groundwater
Secondary: N/A

Contaminant
Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names
- **Pre-Study:** ☐
- **PA, SI, PA/SI, RI, FS, RI/FS:** ☐
- **RD:** ☐
- **IRA-C:** ☐
- **RA-C:** ☐
- **IRA-O, RA-O:** ☐
- **LTM:** ☑
- **PCO:** ☐

Documentation
Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information
Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Cost Over Time Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/01/2010

Estimator Signature: ______________________ **Date:** __________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/01/2010

Reviewer Signature: ______________________ **Date:** __________

Technology Cost Over Time Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2010	2011	2012	2013	2014	2015
Groundwater	$35,556	$35,556	$35,556	$35,556	$35,556	$35,556
Data Management	$36,947	$11,095	$11,095	$11,095	$11,095	$11,095
General Monitoring	$2,470	$2,470	$2,470	$2,470	$2,470	$2,470
Total Technology Cost	$74,973	$49,121	$49,121	$49,121	$49,121	$49,121

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	Total
Groundwater	$213,337
Data Management	$92,421
General Monitoring	$14,822
Total Technology Cost	$320,581

Technology Cost Over Time Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Cost Over Time Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Cost Over Time Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/01/2010

Estimator Signature: ______________________________ **Date:** ______________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/01/2010

Reviewer Signature: ______________________________ **Date:** ______________

Technology Cost Over Time Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2010	2011	2012	2013	2014	2015
Groundwater	$19,818	$19,818	$19,818	$19,818	$19,818	$19,818
Data Management	$21,642	$7,597	$7,597	$7,597	$7,597	$7,597
General Monitoring	$1,918	$1,918	$1,918	$1,918	$1,918	$1,918
Total Technology Cost	$43,379	$29,333	$29,333	$29,333	$29,333	$29,333

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2016	2017	2018	2019	2020	2021
Groundwater	$19,818	$19,818	$19,818	$19,818	$19,818	$19,818
Data Management	$7,597	$7,597	$7,597	$7,597	$7,597	$7,597
General Monitoring	$1,918	$1,918	$1,918	$1,918	$1,918	$1,918
Total Technology Cost	$29,333	$29,333	$29,333	$29,333	$29,333	$29,333

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2022	2023	2024	2025	2026	2027
Groundwater	$19,818	$19,818	$19,818	$19,818	$19,818	$19,818
Data Management	$7,597	$7,597	$7,597	$7,597	$7,597	$7,597
General Monitoring	$1,918	$1,918	$1,918	$1,918	$1,918	$1,918
Total Technology Cost	$29,333	$29,333	$29,333	$29,333	$29,333	$29,333

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2028	2029	2030	2031	2032	2033
Groundwater	$19,818	$19,818	$19,818	$19,818	$19,818	$19,818
Data Management	$7,597	$7,597	$7,597	$7,597	$7,597	$7,597
General Monitoring	$1,918	$1,918	$1,918	$1,918	$1,918	$1,918
Total Technology Cost	$29,333	$29,333	$29,333	$29,333	$29,333	$29,333

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Monitoring

Templates:
System Water - VOCs

Prime Markup: 100 %
Sub Markup: 0 %

	2034	2035	Total
Groundwater	$19,818	$19,818	$515,278
Data Management	$7,597	$7,597	$211,564
General Monitoring	$1,918	$1,918	$49,868
Total Technology Cost	$29,333	$29,333	$776,710

Technology Cost Over Time Report
(with Markups)

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Technology Cost Over Time Report
(with Markups)

Site:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

- **Pre-Study:** ☐
- **PA, SI, PA/SI, RI, FS, RI/FS:** ☐
- **RD:** ☐
- **IRA-C:** ☐
- **RA-C:** ☐
- **IRA-O, RA-O:** ☐
- **LTM:** ☑
- **PCO:** ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw

Technology Cost Over Time Report
(with Markups)

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/01/2010

Estimator Signature: ______________________________ **Date:** ______________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com
Date Reviewed: 06/01/2010

Reviewer Signature: ______________________________ **Date:** ______________

Technology Cost Over Time Report
(with Markups)

Phase:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	2010	2011	2012	2013	2014	2015
Monitoring & Enforcement	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710
Total Technology Cost	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	2016	2017	2018	2019	2020	2021
Monitoring & Enforcement	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710
Total Technology Cost	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	2022	2023	2024	2025	2026	2027
Monitoring & Enforcement	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710
Total Technology Cost	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	2028	2029	2030	2031	2032	2033
Monitoring & Enforcement	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710
Total Technology Cost	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	2034	2035	2036	2037	2038	2039
Monitoring & Enforcement	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710
Total Technology Cost	$2,710	$2,710	$2,710	$2,710	$2,710	$2,710

Technology Cost Over Time Report
(with Markups)

Technology:

Name: Administrative Land Use Controls
Prime Markup: 100 %
Sub Markup: 0 %

	Total
Monitoring & Enforcement	$81,300
Total Technology Cost	$81,300

Estimate Documentation Report

System:

RACER Version: 10.3.0
Database Location: T:\E&I_Projects\AFCEE\4P\PJKS-4P\Eng\Racer\PJKS FFS.mdb

Folder:

Folder Name: PJKS FFS

Project:

Project ID: PJKS FFS
Project Name: Cost Estimate for FFS
Project Category: None

Location
State / Country: COLORADO
City: COLORADO STATE AVERAGE

Location Modifier	Default	User
	1.000	1.000

Options
Database: Modified System
Cost Database Date: 2010
Report Option: Fiscal

Description These are the cost estimates for the Focused Feasibility Study for PJKS.

Estimate Documentation Report

Site Documentation:

Site ID: Alternative 2
Site Name: In situ Bioremediation
Site Type: None

Media/Waste Type

Primary: Groundwater
Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Phase Names

Pre-Study: ☐
PA, SI, PA/SI, RI, FS, RI/FS: ☐
RD: ☐
IRA-C: ☐
RA-C: ☐
IRA-O, RA-O: ☐
LTM: ☑
PCO: ☐

Documentation

Description: This is the cost estimate for Alternative 2, In Situ Bioremediation for the FFS.
Support Team: ASC/ENVR, AFCEE, and Shaw E&I
References: Feasibility Study, Former Air Force Plant PJKS, June 2010

Estimator Information

Estimator Name: Lindsay Archibald
Estimator Title: Geologist
Agency/Org./Office: Shaw
Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8150
Email Address: lindsay.archibald@shawgrp.com
Estimate Prepared Date: 06/15/2010

Estimator Signature: ______________________ **Date:** ____________

Reviewer Information

Reviewer Name: Thomas Cooper
Reviewer Title: Project Manager
Agency/Org./Office: Shaw

Estimate Documentation Report

Business Address: 7604 Technology Way
Suite 300
Denver, CO 80237
Telephone Number: 720-554-8163
Email Address: thomas.cooper@shawgrp.com

Date Reviewed: 06/15/2010

Reviewer Signature: ______________________________ **Date:** ______________

Estimated Costs:

Phase Names		Direct Cost	Marked-up Cost
LTM		$1,200,248	$2,349,402
	Total Cost:	$1,200,248	$2,349,402

Estimate Documentation Report

Phase Documentation:

Phase Type: Long Term Monitoring
Phase Name: LTM
Description: This is the cost estimate for LTM for the life of the project for the FFS, for in-situ bioremediation and monitoring and 5-year reviews and well abandonment.

Start Date: June, 2010
Labor Rate Group: System Labor Rate
Analysis Rate Group: System Analysis Rate

Phase Markups: System Defaults

Technology Markups	Markup	% Prime	% Sub.
MONITORING YEAR 0-5	Yes	100	0
Five-Year Review	Yes	100	0
ENVIRONMENTAL COVENANT	Yes	100	0
FINAL ROUND OF INJECTIONS	Yes	100	0
MONITORING YEAR 6-30	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0
Well Abandonment	Yes	100	0

Total Marked-up Cost: $2,349,402

Technologies:

Estimate Documentation Report

Technology Name: **Monitoring (# 1)**
User Name: **MONITORING YEAR 0-5**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Model Name		MONITORING YEAR 0-5	n/a
Groundwater		Yes	n/a
Surface Soil		No	n/a
Surface Water		No	n/a
Subsurface Soil		No	n/a
Sediment		No	n/a
Soil Gas		No	n/a
Air		No	n/a
Site Distance (One-way)		25	MI
Safety Level		D	n/a
Groundwater			
Required Parameters			
Average Sample Depth		60	FT
Samples per Event (First Year)		50	n/a
Samples per Event (Out Years)		50	n/a
Number of Events (First Year)		1	n/a
Number of Events (Out Years)		1	n/a
Number of Years (Out Years)		5	n/a
Secondary Parameters			
Primary Analytical Template	System Water - VOCs	System Water - VOCs	n/a
Secondary Analytical Template	None	None	n/a
Turnaround Time	Standard (21 Days)	Standard (21 Days)	n/a
Data Package/QC	Stage 1	Stage 1	n/a
Sampling Method	Existing Wells - Low Flow Pump	Existing Wells - Pump	n/a
Number of Wells/Day	6	6	EA
Contain Purge Water	Yes	Yes	n/a
QA/QC			
Secondary Parameters			
Split Samples	1: 10	1: 0	EA
Field Duplicate Samples	1: 10	1: 10	EA

Estimate Documentation Report

Technology Name: **Monitoring (# 1)**
User Name: **MONITORING YEAR 0-5**

Description	*Default*	*Value*	*UOM*
QA/QC			
Secondary Parameters			
Rinse Blanks (per Round)	1	0	EA
Trip Blanks (per Day)	1	1	EA
Matrix Spikes/Matrix Spike Duplicates	1: 20	1: 20	EA
Data Management			
Secondary Parameters			
Monitoring Plan	Standard	Standard	n/a
Lab Data Review	Stage 1	Stage 1	n/a
Submit Data Electronically	Yes	Yes	n/a
Monitoring Reports	Abbreviated	Abbreviated	n/a

Comments:

Estimate Documentation Report

Technology Name: Five-Year Review (# 1)

Description	Default	Value	UOM
System Definition			
Required Parameters			
Site Complexity		Low	n/a
Document Review		Yes	n/a
Interviews		No	n/a
Site Inspection		Yes	n/a
Report		Yes	n/a
Travel		No	n/a
Rebound Study		No	n/a
Start Date		June-2015	n/a
No. Reviews		6	EA
Document Review			
Required Parameters			
5-Year Review Check List		Yes	n/a
Record of Decision		Yes	n/a
Remedial Action Design & Construction		Yes	n/a
Close-Out Report		Yes	n/a
Operations & Maintenance Manuals & Reports		Yes	n/a
Consent Decree or Settlement Records		Yes	n/a
Groundwater Monitoring & Reports		Yes	n/a
Remedial Action Required		Yes	n/a
Previous 5-Year Review Reports		Yes	n/a
Site Inspection			
Required Parameters			
General Site Inspection		Yes	n/a
Containment System Inspection		No	n/a
Monitoring Systems Inspection		No	n/a
Treatment Systems Inspection		No	n/a
Regulatory Compliance		Yes	n/a
Site Visit Documentation (Photos, Diagrams, etc.)		Yes	n/a
Report			
Required Parameters			
Introduction		Yes	n/a

Estimate Documentation Report

Technology Name: **Five-Year Review (# 1)**

Description	*Default*	*Value*	*UOM*
Report			
Required Parameters			
Remedial Objectives		Yes	n/a
ARARs Review		Yes	n/a
Summary of Site Visit		Yes	n/a
Areas of Non Compliance		Yes	n/a
Technology Recommendations		Yes	n/a
Statement of Protectiveness		Yes	n/a
Next Review		Yes	n/a
Implementation Requirements		Yes	n/a

Comments:

Estimate Documentation Report

Technology Name: **Administrative Land Use Controls (# 1)**
User Name: **ENVIRONMENTAL COVENANT**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Rename Model		ENVIRONMENTAL COVENANT	n/a
Planning Documents		No	n/a
Implementation		No	n/a
Monitoring & Enforcement		Yes	n/a
Monitoring & Enforcement: Start Date		2010	n/a
Modification/Termination		No	n/a
Type of Site		Former Government Site	n/a
Monitoring & Enforcement			
Required Parameters			
Duration of Monitoring/Enforcement		30	Years
Notice Letters		No	n/a
Guard Service/Security		No	n/a
Reports & Certifications		No	n/a
Site Visits/Inspections		Yes	n/a
Site Visits/Inspections: Number		1	EA
Site Visits/Inspections: Safety Level		D	n/a
Site Visits/Inspections: Duration		1	Days
Site Visits/Inspections: Number of People		1	EA
Site Visits/Inspections: Frequency		Annually	n/a
Site Visits/Inspections: Airfare		0	$ Per Ticket
Site Visits/Inspections: Mileage		0	MI

Comments:

Estimate Documentation Report

Technology Name: **User Defined Estimate (# 1)**
User Name: **FINAL ROUND OF INJECTIONS**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Model Name		FINAL ROUND OF INJECTIONS	n/a
WBS Type		HTRW	n/a
Selected WBS		342.11.04	n/a
Safety Level		D	n/a

Comments: This estimate accounts for the injection of EEO into 32 vertical wells and 10 horizontal wells.

Estimate Documentation Report

Technology Name: **Monitoring (# 2)**
User Name: **MONITORING YEAR 6-30**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Model Name		MONITORING YEAR 6-30	n/a
Groundwater		Yes	n/a
Surface Soil		No	n/a
Surface Water		No	n/a
Subsurface Soil		No	n/a
Sediment		No	n/a
Soil Gas		No	n/a
Air		No	n/a
Site Distance (One-way)		25	MI
Safety Level		D	n/a
Groundwater			
Required Parameters			
Average Sample Depth		60	FT
Samples per Event (First Year)		25	n/a
Samples per Event (Out Years)		25	n/a
Number of Events (First Year)		1	n/a
Number of Events (Out Years)		1	n/a
Number of Years (Out Years)		25	n/a
Secondary Parameters			
Primary Analytical Template	System Water - VOCs	System Water - VOCs	n/a
Secondary Analytical Template	None	None	n/a
Turnaround Time	Standard (21 Days)	Standard (21 Days)	n/a
Data Package/QC	Stage 1	Stage 1	n/a
Sampling Method	Existing Wells - Low Flow Pump	Existing Wells - Pump	n/a
Number of Wells/Day	6	6	EA
Contain Purge Water	Yes	Yes	n/a
QA/QC			
Secondary Parameters			
Split Samples	1: 10	1: 0	EA
Field Duplicate Samples	1: 10	1: 10	EA

Estimate Documentation Report

Technology Name: **Monitoring (# 2)**
User Name: **MONITORING YEAR 6-30**

Description	*Default*	*Value*	*UOM*
QA/QC			
Secondary Parameters			
Rinse Blanks (per Round)	1	0	EA
Trip Blanks (per Day)	1	1	EA
Matrix Spikes/Matrix Spike Duplicates	1: 20	1: 20	EA
Data Management			
Secondary Parameters			
Monitoring Plan	Standard	Abbreviated	n/a
Lab Data Review	Stage 1	Stage 1	n/a
Submit Data Electronically	Yes	Yes	n/a
Monitoring Reports	Abbreviated	Abbreviated	n/a

Comments:

Technology Name: **Well Abandonment (# 1)**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Safety Level		D	n/a
Abandon Wells			
Required Parameters			
Technology/Group Name		Deep Lariat Gulch Wells	n/a
Number of Wells		10	EA
Well Depth		500	FT
Well Diameter		4	IN
Well Abandonment Method		Overdrill / Removal	n/a
Formation Type		Unconsolidated	n/a

Comments:

Estimate Documentation Report

Technology Name: **Well Abandonment (# 2)**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Safety Level		D	n/a
Abandon Wells			
Required Parameters			
Technology/Group Name		Horizontal Wells	n/a
Number of Wells		10	EA
Well Depth		500	FT
Well Diameter		4	IN
Well Abandonment Method		Abandon In-Place	n/a
Formation Type		Unconsolidated	n/a

Comments:

Technology Name: **Well Abandonment (# 3)**

Description	*Default*	*Value*	*UOM*
System Definition			
Required Parameters			
Safety Level		D	n/a
Abandon Wells			
Required Parameters			
Technology/Group Name		Remaining Wells	n/a
Number of Wells		350	EA
Well Depth		70	FT
Well Diameter		4	IN
Well Abandonment Method		Abandon In-Place	n/a
Formation Type		Unconsolidated	n/a

Comments: