Draft Final

Demonstration of Surfactant-Enhanced Aquifer Remediation of Chlorinated Solvent DNAPL at Operable Unit 2, Hill AFB, Utah

Prepared for:

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

OO-ALC/EMR
Hill Air Force Base
Ogden, Utah

Prepared by

INTERA
A Duke Engineering & Services Company

in cooperation with:
Radian International, LLC
The University of Texas at Austin

June 1997

Duke Engineering & Services℠
A Duke Energy Company

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

December 9, 1998

Mr. Christian J. McGrath, PG
CEWES-ES-Q
US Army Engineer Research & Development Center
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199

Dear Chris,

SUBJECT: HILL AFB SURFACTANT FLOOD DOCUMENTS

Please find enclosed the Phase I and II Work Plans and the Project Plan for wellfield installation and aquifer testing that you requested. I was sorry to have missed your visit to our offices during the UTCHEM short course. I hope to meet you soon. Perhaps the Florida Petroleum Reprocessors project that EPA Region IV has approached us about may provide that opportunity.

Sincerely,

Dick Jackson

R.E.Jackson
Manager, Geosystems & Geochemistry

Enclosures (3)

cc: S. Taffinder, AFCEE
H.W.Meinardus

MITRETEK
SYSTEMS

19 November 1998
H050-L-048

Mr. Sam Taffinder
Technology Transfer Division
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Subject: Technical Review of the DNAPL Tracer Tests at Air Force Plant 4, Fort Worth, Texas

Reference: Air Force Center for Environmental Excellence Contract Number F41624-98-R-8021

Dear Mr. Taffinder:

Mitretek Systems reviewed the subject document prepared by Eckenfelder, Inc., for completeness and technical content. In general, the document is complete and well writen. The estimates of DNAPL mass made by this technology should be considered as a lower bounds and may be orders of magnitude lower than the actual mass present at the site. The attached comments discuss the limitations of the technology and address other technical issues.

Innovative Technology in the Public Interest

If you have any questions regarding our review comments, please contact me at (210) 408-4544.

Sincerely,

Marc D. Gill

Marc D. Gill, Ph.D., P.E.
Center for Science and Technology

MDG/lem

Enclosure

cc: Marty Faile, AFCEE/ERT

TECHNICAL REVIEW OF THE DNAPL TRACER TESTS AT AIR FORCE PLANT 4, FORT WORTH, TEXAS

Mitretek Systems performed a technical review of a report entitled "Tracer Tests at Air Force Plant 4" by Eckenfelder, Inc. Working as a subcontractor to Jacobs Engineering Group, Eckenfelder performed Dense Non-Aqueous Phase Liquid Tracer Tests (DTTs) in Building 181 and in the East Parking Lot at Air Force Plant 4. The objective was to estimate the quantity of DNAPL present at each site for the design of a remedial action. The evaluation of specific remedial alternatives, such as surfactants, was not included in this project.

The test results suggest that between 100 kg and 200 kg of DNAPL are within the test volume (approximately 86 m^3) at Building 181. This is equivalent to 1.3 to 2.3 kg/m^3 in the aquifer at that site. At the F-218 site, the test results suggest that between 360 kg and 720 kg of DNAPL are within the test volume (approximately 167 m^3). This is equivalent to 2.2 to 4.3 kg/m^3 in the aquifer at the F-218 site.

The document is generally complete and well written. It provides a detailed description of the work performed, the data collected, and the methods used to interpret the data. The document is very frank in discussing the limitations of the test procedure, and clearly states that the results are semi-quantitative and should be taken as a lower bounds of the DNAPL contamination present. This is perhaps the most significant point made in the document.

The DTT test, as described in the document, is a relatively new and innovative approach for estimating the quantity of DNAPL *in situ*. However, it is subject to the following limitations:

1. The interiors of large accumulations of DNAPL or DNAPL in dead-end pores are highly inaccessible to the mass transport of the tracers. This means that the DNAPL-water surface contact area available for mass transport of the partitioning tracer may be orders of magnitude smaller than if the same quantity of DNAPL were distributed as small droplets, and the estimates of DNAPL source mass by this method may be orders of magnitude too small.

2. Movement of DNAPL is generally downward, except where layers of low permeability or the boundaries of units with significantly differing grain size lithologies are encountered, at which point, the DNAPL may move laterally until a downward preferential path is encountered. The movement of the aqueous tracer and carrier fluid, however, is generally horizontal and may miss DNAPL lower in the aquifer.

3. The partitioning of the tracer is affected by the presence of other organic contaminants, such as grease and oils, which might also retard the tracers. This would result in a false positive interpretation of the test results.

4. Inhomogeneity of the aquifer may result in anomalous results because advection will not be uniform. The tracer will move preferentially in higher conductivity units of the aquifer, bypassing finer and tighter units.

5. The interpretation of results relies upon calibration of the computer model to concentrations of a conservative tracer and then adjusting model parameters in an attempt to fit the response of the non-conservative tracers observed in the field.

6. The DTT approach gives no information about the distribution of the DNAPL in the soil layers. For example, the DNAPL may be diffused into the pores of a fine clay, as thin layers in a weathered shale, or as a hydrophobic "blob" in the soil. The effectiveness of various remedial methods will depend upon how it is distributed.

A better approach for estimating DNAPL mass and distribution is to use a push technology (e.g., cone penetrometer) to obtain soil cores and determine the lithology of the site. Discrete samples may then be taken from the cores at the same scale as the heterogeneity of soil structure and analyzed for DNAPL concentration. Contrary to the statements in the document, coring and laboratory analysis may be done economically and will provide more information for the design of a remediation.

The computer model used in this work is relatively sophisticated. It is one of the first models to include calculations for the diffusion of DNAPL into clay lenses, which is a very important mechanism of DNAPL "storage" within an aquifer.

During our review of the document we noted that the scale shown in the legends of the Figures 4-3, 4-4, and 4-5 are labeled incorrectly. More significantly, we also noted that the well depths and positions of the screens are shown incorrectly in Figure 4-6. Based on the boring logs and land survey results, the bottoms of the screens all appear to be above the weathered shale and bedrock. DNAPL may have accumulated in thin layers in the shale below the elevation of the well screens and likely would not be fully contacted by the tracers.

MEMORANDUM FOR AFCEE/ERT
ATTN: Sam Taffinder

02 JUN 1998

SUBJECT: Contract F41624-95-8010, Intera Inc.

FROM: HSC/PKVBB (Grace Elizalde)

1. Attached for your review and signature are Public Vouchers 1 - 14 for subject contract. Additionally, the final DD250Z is attached for your review and signature. The period of performance expired on 28 Nov 97. Request that you expedite your review so that final closeout of the contract can be accomplished. Closeout procedures require that the assigned Contracting Officer Representative coordinate that all deliverables required by this order have been received and accepted. If you concur that performance on this order is complete and deliverables have been received and accepted, please sign at the bottom of this memo.

2. Provided for your review is the Actual Expenditures Tracking Report from CAMS listing all invoices submitted by Intera Inc. for the subject contract.

Grace L. Elizalde
GRACE L. ELIZALDE
Contract Administrator

Attachment
DD250Z
CAMS report

MEMO FOR RECORD

TO: HSC/PKVBB

All deliverables for this order have been received and accepted. Please process the final closeout for this contract.

Sam A. Taffinder

Post-it® Fax Note 7671

To Carol Montillotti	Date 15 Sep 98 # of pages ▸ 02
Co./Dept. DCMC	From Mr. Sam Taffinder
Phone #	Co. HQ AFCEE/ERT
Fax # (512) 928-8994	Phone # (210) 536-4366
	Fax #

MATERIAL INSPECTION AND RECEIVING REPORT

Form Approved
OMB No. 0704-0248

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO EITHER OF THESE ADDRESSES.
SEND THIS FORM IN ACCORDANCE WITH THE INSTRUCTIONS CONTAINED IN THE DFARS, APPENDIX F-401.

1. PROC. INSTRUMENT IDEN. (CONTRACT): F41624-95-C-8010 | (ORDER) NO.
6. INVOICE NO./DATE
7. PAGE | OF
8. ACCEPTANCE POINT: D

2. SHIPMENT NO.: DES-000-1Z
3. DATE SHIPPED: 1-15-98
4. B/L
TCN
5. DISCOUNT TERMS: N/A

9. PRIME CONTRACTOR CODE: OW330
INTERA Inc.
9111 Research Blvd
Austin, TX 78758

10. ADMINISTERED BY CODE: S4404A
DCMC San Antonio
615 E. Houston St. PO Box 1040
San Antonio, TX 78294-1040

11. SHIPPED FROM (if other than 9) CODE | FOB:
Same as Block 9

12. PAYMENT WILL BE MADE BY CODE: HQ0339
DFAS - Columbus
West Entitlement Operations
PO Box 182381
Columbus, OH 43218-2381

13. SHIPPED TO CODE: FA8900
AFCEE/ERT
8001 Arnold Drive ATTN: Sam Taffinder
Contract No.: F41624-95-C-8010
Brooks AFB, TX 78235-5853

14. MARKED FOR CODE

15. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (Indicate number of shipping containers - type of container - container number.)	17. QUANTITY SHIP/REC'D*	18. UNIT	19. UNIT PRICE	20. AMOUNT
0001	Surfactant Enhanced Aquifer Remediation	1	LO		
0002	Support	1	LO		
0003	Data	1	LO		

21. CONTRACT QUALITY ASSURANCE

A. ORIGIN
☐ CQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

DATE | SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

B. DESTINATION
☐ CQA ☐ ACCEPTANCE of listed items has been made by me or under my supervision and they conform to contract, except as noted herein or on supporting documents.

10 Sep 98 | Sam R. Taffinder
DATE | SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

22. RECEIVER'S USE
Quantities shown in column 17 were received in apparent good condition except as noted.

10 Sep 98 | Sam R. Taffinder
DATE | SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

* If quantity received by the Government is the same as quantity shipped, indicate by (X) mark, if different, enter actual quantity received below quantity shipped and encircle.

23. CONTRACTOR USE ONLY
ease forward signed copy to DCMC San Antonio

SLIP#: 1409

To Team Chief: Mr Sam Taffinder, ERT, 4366

DATE 22-May-98

CONTRACT NUMBER/DELIVERY ORDER NUMBER: F41624-95-C-8010 / 0

BILLING PERIOD: --

Return to Data Specialist:
Completed Invoice Routing Slip
Signed and dated Invoice
Actual Expenditure Tracking Report

INVOICE NUMBER: SHIPMENT/VOUCHER NO: DES-000-1Z

THE FOLLOWING INVOICE IS FORWARDED FOR YOUR REVIEW AND ACTION. PLEASE APPROVE/DISAPPROVE AND FORWARD TO THE DATA SPECIALIST INDICATED BELOW:

DD250 (4 DAY SUSPENSE)

APPROVAL DATE: 10 Sep 98 DISAPPROVAL DATE: ______________

DATA SPECIALIST: Ingra Haynes, MSI/SRD, 6317

COR: Mr Sam Taffinder, ERT, 4366
Contract Manager: FAILE
Contract Owner: vacant

Administrator: Ms Grace Elizalde, PKVB
CO: Mr John Caporal, PKVBB, 2394
Buyer: vacant

DE&S
Duke Engineering & Services

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

June 9, 1998

Major Edward Heyse
AFIT/ENV
2950 P Street
Wright Patterson AFB OH
45433

Dear Ed,

Please find enclosed copies of the reports on our two surfactant floods and the five associated PITTs conducted in 1996 and 1997 at Hill AFB OU2. We are particularly keen to have a set of both reports deposited at AFIT where students might make use of the data collected at OU2. The data is on the diskettes included with the final reports to AFCEE and AATDF.

Thanks again for inviting me to talk at AFIT, which was a great pleasure. I will forward a copy of NAPLANAL shortly.

Sincerely,

Dick Jackson.

Richard E. Jackson

cc. S.Taffinder, AFCEE
G.A.Pope, UT
G.J.Hirasaki, Rice University
C.A.Miller, Rice University
H.W.Meinardus
J.F.Pickens

Enclosures (2)

PARSONS

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8206

May 26, 1998

Mr. Sam Taffinder
AFCEE/ERT
3207 North Road
Brooks AFB, Texas 78235-5357

Contract: F41624-97-C-8005
Demonstration of a Risk-Based Approach to Determine the Remedial Requirements at Abandoned Firing Ranges

Subject: CDRL Data Item No. A009
Transmittal of the Draft Final Work Plan for Site CF-27, Rifle Range B, Lackland Air Force Base, Texas

Dear Mr. Taffinder:

Parsons Engineering Science, Inc. (Parsons ES) is pleased to provide you with the draft final work plan for Site CF-27, Rifle Range B at Lackland Air Force Base, Texas. This document was also submitted today for regulatory review, as shown on the attached cover letter from Mr. Richard Trevino of Lackland AFB. Regulatory review comments were requested by June 19, 1998. We are also providing copies of the draft final work plan to the Air Force oversite contractor and the Lackland AFB Point of Contact (POC), as listed below.

If you have any questions or comments regarding this document, please do not hesitate to call me at (303) 764-1913.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Kent A. Friesen

Kent A. Friesen, P.E.
Project Manager

cc: Mr. Don Ficklen, 37 CES/CEV
Dr. Sam Brock, Waste Policy Institute
Mr. David Miller, HSC/PKVBB (transmittal letter only)

S:\ES\WP\PROJECTS\731994\112.doc

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS HUMAN SYSTEMS CENTER (AFMC)
BROOKS AIR FORCE BASE, TEXAS

20 MAY 1998

MEMORANDUM FOR The Environmental Company, Inc.
2046 Old Ivy Road, Suite 300
P O Box 5127
Charlottesville VA 22905

FROM: Human Systems Center/PKVBB
3207 North Road Bldg. 532
San Antonio, Texas 78235-5363

SUBJECT: Contract F41624-95-D-8002, Delivery Order 0012, Public Voucher 3112-18

1. Public Voucher #3112-18 dated 28 Mar 98 was submitted for payment and paid by DFAS on 29 Apr 98. A copy was submitted to HSC/PKVBB and has been reviewed by the Contracting Officer Representative, Sam Taffinder.

2. In the process of Mr. Taffinder's review, he has noted an excessive amount of cumulative man-hours for the senior toxicologist, mid-level toxicologist and junior hazardous waste specialist were charged for the preparation of the Draft report. Request that you provide any backup that will support the total man-hours charged for this task. This would include payroll records as well as any other supporting verification.

3. Submit the required information to the above address, Attn: Grace Elizalde, no later than 22 May 1998. If you have any questions or require additional information, contact Grace Elizalde at (210) 536-5418 or the undersigned at (210) 536-2394.

John G. Caporal
JOHN G. CAPORAL
Contracting Officer

cc: AFCEE/ERT/Sam Taffinder

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OGDEN AIR LOGISTICS CENTER (AFMC)
HILL AIR FORCE BASE, UTAH

17 Apr 98

MEMORANDUM FOR Mr. Sam Jaffinder

FROM: OO-ALC/PK-3
7920 Georgia Street, Bldg. 1146
Hill AFB, UT 84056

SUBJECT: Request for Source Selection Information

1. The Ogden Air Logistics Center is in the process of conducting a formal Source Selection for the Environmental Construction/Services Program. The purpose of this program is to provide environmental design and remediation, long term monitoring, and operations and maintenance to support the Installation Remediation Program at Hill Air Force Base.

2. One of the considerations in proposal evaluation is the verification of the offerors' past and present performance on contracts which reflect the offeror's ability to perform on the proposed effort. We depend on information received from organizations such as yours, which have first hand experience with an offeror, for the evaluation of the offeror's performance on those contracts.

3. Our areas of interest in the offeror are summarized in the enclosed questionnaire. Our schedule is extremely tight and we need your written response no later than 13 calendar days after your receipt of this letter. In order to meet our milestone dates, we need all questionnaires returned by 30 Apr 98.

4. To assist you in preparing your response and expediting your reply, your questionnaire may be filled out and faxed to DSN 777-0829 or (801) 777-0829, attention Lisette LeDuc. This fax machine is in a secure area and is capable of receiving messages 24 hours a day. Please call the PCO, Capt Julie Wittkoff, at DSN 777-4809 or (801) 777-4809 if you have any questions. Please note that once the questionnaire is filled out, it becomes source selection sensitive and needs to be handled accordingly. If you choose to return the questionnaire by mail, it should be double wrapped with the inside cover marked Source Selection Sensitive. Please mail the questionnaires to the address shown above, marking it Attention Lisette LeDuc.

5. Respondents' names will be kept confidential and will not be released to anyone. Your help is greatly appreciated and your prompt response will be one of the keys to the successful and timely completion of this source selection.

Lisette K. LeDuc
LISETTE K. LEDUC
Performance Confidence Assessment Group

1 Atch
Questionnaire

This document is <u>Source Selection Sensitive</u> when completed.

PAST PERFORMANCE QUESTIONNAIRE

General instructions:

⇒ *Most survey questions only requires a multiple choice response.* Estimated time to complete this survey is 10-15 minutes. Please clearly write in ink or type. Thank you very much for taking your time to complete this survey.

I. CONTRACT IDENTIFICATION

A. Contractor: Intera Inc.

B. Contract Number: F41624-95-C-8010

C. Contract Type: Completion Contract

D. Competitive? Yes No

E. Follow-on contract? Yes No

F. Period of performance: 19 Jun 95 through 30 Apr 98

G. Initial contract cost: $798K

H. Current/final contract cost: $1,018K

I. Reasons for differences between initial contract cost and final contract costs:
Reasons were unforeseen changes in site conditions, unexpected schedule delays, and the contractor inexperience with working for the Air Force.

J. Description of services provided:
Contractor provided the man-hours (labor), materials, and technical services to successfully demonstrate the effectiveness of Surfactant Injection in the removal of DNAPL.

II. EVALUATOR IDENTIFICATION (<u>Individual's names will be held in the strictest of confidence.</u>)

A. Evaluator name: Sam A. Taffinder

B. Evaluator title: Environmental Scientist

C. Phone number: DSN 240-4366

D. Evaluator facsimile number: DSN 240-4330

Post-it® Fax Note 7671	Date 07 May 98 # of pages ▸ 09
To Lisette LeDuc	From Sam A. Taffinder
Co./Dept. OO-ALC/PKS	Co. HQ AFCEE/ERT
Phone #	Phone # DSN 240-4366
Fax # (801) 777-0829	Fax # 240-4330

This document is Source Selection Sensitive when completed.

PROGRAM MANAGEMENT

1. Did the contractor provide for effective overall contract management?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

2. Did the contractor demonstrate a sound, well-managed approach in its organizational structuring so that sufficient resources were dedicated to timely meeting *program and contract requirements* and successful resolution of problems and challenges?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

3. Did management exhibit a consistent effort throughout the contract period to identify potential risks that might impact performance, and take appropriate action to mitigate those risks?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

4. Did management demonstrate a genuine desire to be responsive to the government-customer's needs, and a willingness to make adjustments to schedules, products or services in order to meet those needs?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

5. Did the contractor respond positively and promptly to technical directions, contract change orders, negotiations, and in resolving other issues?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

6. Did the contractor have a stable work force with *minimal personnel turnover* that maintained *project continuity*?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

This document is Source Selection Sensitive when completed.

7. Was the contractor successful in responding to "emergency" situations (e.g., requests for accelerated schedules, manage shifting workload, and staffing under changing conditions)?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

8. Was the contractor easily accessible and could be contacted quickly for urgent communications?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

9. Was the contractor able to resolve contract performance problems without extensive guidance from the government-customer?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

10. Did the contractor successfully and proactively complete all work tasks outlined &/or requested and did their actions bring consistent "value" to the project?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

11. Did the contractor establish a good, smooth working relationship with associate contractor(s) or the incumbent contractor, if necessary, at the beginning of the contract to ensure an effective transition?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

12. Were products &/or services delivered on time to established milestones without waiver or extensions (taking into account all excusable delays)?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

This document is Source Selection Sensitive when completed.

PERSONNEL AND STAFFING

1. Was the contractor able to staff positions with sufficient personnel who were adequately trained, certified, and licensed to perform the tasks/services of the contract prior to contract start up and throughout the life of the contract?

EXCELLENT GOOD FAIR POOR NOT APLLICABLE
Comments:

2. Were quality replacement personnel, if necessary, supplied by the contractor in a timely manner?

EXCELLENT GOOD FAIR POOR NOT APLLICABLE
Comments:

SUBCONTRACTOR MANAGEMENT

1. Did the contractor demonstrate a sound subcontractor management program to ensure subcontractor-provided services or products conformed with technical requirements and were coordinated, integrated, and delivered on time?

EXCELLENT GOOD FAIR POOR NOT APLLICABLE
Comments:

2. Was management successful in averting or minimizing delays due to problems with subcontractors, suppliers, material availability, and in precluding work stoppages due to employee disputes, etc.?

EXCELLENT GOOD FAIR POOR NOT APLLICABLE
Comments:

3. Did the contractor track subcontractor performance and take appropriate measures with substandard subcontractor performance?

EXCELLENT GOOD FAIR POOR NOT APLLICABLE
Comments:

This document is Source Selection Sensitive when completed.

4. Were the prime contractor/subcontractor teaming arrangements effective? (In other words, were subcontracting tiers limited in order to maintain and control oversight?)

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

TECHNICAL

1. Did the contractor demonstrate a thorough understanding of the technical requirements of the contract?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

2. Did the contractor's quality control program provide an effective method for preventing deficiencies and correcting existing deficiencies?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

3. Did the contractor exhibit a thorough knowledge of environmental protection regulations and requirements and did they adhere to them?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

4. Did the contractor have an adequate environmental, public health and safety program &/or procedures in place?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

5. Did the contractor suffer considerable lost time due to accidents or other significant incidents?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

This document is Source Selection Sensitive when completed.

6. Did the contractor propose alternative value-added/cost saving measures or materials such as engineering changes, streamlining or eliminating processes, or otherwise seek to reduce cost, improve maintainability, increase efficiencies, etc., that benefited the government?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

7. Did the contractor meet all requirements and schedules to update and maintain technical manuals, technical orders, specifications and as-built drawings?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

8. Did the contractor meet all requirements (e.g., timely, accurate) for the collection, documentation, and reporting of data and for the documentation of project status as required by the contract?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

9. Was the contractor successful in resolving technical problems or questions?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

10. Did the contractor respond to requests for technical assistance (both on-site and off-site), warranty issues or repairs in a timely manner?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

11. Did the contractor have adequate facilities, computer-support equipment, tooling, and resources needed for contract support?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

12. Did the contractor produce designs that were accurate and resulted in a minimum of clarifications or changes in the field?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

13. Was the contractor assessed any citations, fines or penalties directly or indirectly related to work under this contract?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

14. Did the contractor foster and maintain positive relationships with U.S., state and local government regulators, the local community (e.g., landowners), and other stakeholders involved in the work (e.g., Restoration Advisory Board, Sierra Club, etc.)?

    EXCELLENT GOOD FAIR POOR NOT APLLICABLE
    Comments:

COST

1. Did the contractor perform all contractual requirements within the contracted costs?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

2. Were the contractor's price proposals timely, accurate and free from ambiguity and excessive costs?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

3. If your contract was a cost-type contract, how close was the estimated costs to the actual costs?

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

4. Were the prime contractor/subcontractor teaming arrangements efficient with respect to cost? (In other words, were subcontracting tiers limited to minimize added costs due to overhead?)

   EXCELLENT GOOD FAIR POOR NOT APLLICABLE
   Comments:

GENERAL QUESTIONS

1. Was this contract partially terminated for default or convenience?

   Yes or No If yes, which? Default or Convenience

   If yes, please explain (e.g., inability to meet cost, performance, or delivery schedules).

2. Are there any pending terminations? Yes or No

   If no, was termination ever considered? Yes or No

   Please explain any "yes" answers and indicate the status.

3. If this was a cost-type contract, were there any cost overruns caused by the contractor?

   Yes or No | If "yes," how many? One | For what dollar amount? $ 250K

4. Did the contractor request any specification relief?

   Yes or No

   If "yes," was there an impact on system performance, cost, or delivery?

5. How did you perceive the financial capability/stability of this contractor to meet the contract requirements?

   Excellent Good Fair Poor

6. What were the contractor's greatest strengths in the performance of the contract?

Contractor's greatest strengths were they Technical Expertise and their teaming with subcontractors.

7. What were the contractor's greatest weaknesses in the performance of the contract?

Contractor's greatest weakness was their lack of discipline to fiscally manage the effort within budget.

8. Would you have any reservations about soliciting this contractor in the future or having them perform one of your critical and demanding programs?

   Yes or No

   If "yes," will you please share your reservations?

9. Please share any other comments on areas that may not have been covered.

The results, findings, conclusions, ~~and~~ recommendations of which were presented in the Draft and Final Technical Report were fully endorsed by the customer and by the regulatory community.

The following people provided input for this survey: (Reminder: Individual's names will be held in the strictest of confidence.)

NAME	**TITLE/POSITION**

Again, thank you very, very much for your time and your responses. ***Please return this completed questionnaire to:***

00-ALC/PK-3
Attn.: Lisette K. LeDuc
7920 Georgia Street, Building 1146
Hill Air Force Base, UT 84056-5823

Or FAX to: **801-777-0829 or 801-777-5514**

DE&S
Duke Engineering & Services

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

April 13, 1998

Mr. Sam Taffinder
AFCEE/ERT
AFCEE HQ
3207 North Road
Brooks AFB, TX 78235-5363

Dear Mr. Taffinder,

Duke Engineering & Services is submitting a proposal to Hill Air Force Base, Utah to provide services specified in the Environmental Construction/Services RFP - Number F42650-98-R-003. As part of our proposal we have provided Past Performance information related to our contract with the Air Force Center for Environmental Excellence (AFCEE) for the Characterization & Remediation of DNAPLs at Operable Unit 2, Hill Air Force Base, Utah . We are enclosing a copy of the project description for your information. With this letter, DE&S gives you permission to release to the Hill Air Force Base Proposal Evaluation team information on our performance as your contractor. Thank you in advance for your support to this effort.

Best regards,

John Pickens
Vice President, GeoEngineering Services
Federal Group

cc: Captain Julie Wittcoff, OO-ALC/PKOE, Hill Air Force Base

Enclosure: Project Description

DE&S
Duke Engineering & Services

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

April 8, 1998

Mr. Sam Taffinder
Contracting Officer's Representative
AFCEE/ERT
3207 North Road
Brooks AFB, Texas 78235-5363

Re: Reference Form for Registered Corrective Action Specialist Application

Dear Sam:

It was good to talk with you today and catch up. And, thank you for agreeing to serve as a reference.

Enclosed please find a TNRCC Corrective Action Reference Form. Duke Engineering & Services (DE&S) is currently in the process of re-applying for LPST Corrective Action Specialist designation. Since INTERA Inc. changed its name to DE&S in 1997, this name change must also carry over to INTERA's Corrective Action Specialist registration with the TNRCC. Please complete the attached recommendation form for the services DE&S has provided for you at Hill Air Force Base, Utah and return to DE&S.

I've enclosed an SASE for your convenience. Please note that they ask that the form be filled out in blue ink. If you should have any questions regarding this request, please feel free to contact me at 512-425-2018. Thanks again!

Sincerely,

Paul

Paul B. Cravens, P.E.
Manager
Regulatory Compliance and Environmental Services

enclosures

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

TNRCC CORRECTIVE ACTION REFERENCE FORM
LPST CORRECTIVE ACTION SPECIALIST

INSTRUCTIONS FOR PERSON COMPLETING THIS REFERENCE STATEMENT

The rules of the Texas Natural Resource Conservation Commission (TNRCC) (30 TAC Chapter 334, Subchapter J) require that an applicant seeking registration as an LPST Corrective Action Specialist submit sworn statements from three different clients/companies, not related by blood or marriage, for whom the applicant performed corrective action services **within the immediately preceding 24 months. Please limit each reference to one specific job done within one specific time period. Please also give the specific physical address of the job site.** (If no physical address exists, state directions to the job site from a point, such as an intersection, easily found on a highway map.) Be sure that the entire form has been filled out completely and accurately. Any incomplete or omitted information may delay the processing of the application. The form should be completed legibly and **signed in blue ink.**

SECTION I - BUSINESS NAME OF APPLICANT

Name of Business/Company applying for registration

Duke Engineering & Services

SECTION II - CLIENT INFORMATION (customer for whom the work was done)

Client Representative (name of person completing form):	Title of Client Representative		
a) Sam A. Taffinder	Project Manager		
Business Name: b) Technology Transfer Division, Air Force Center For Environmental Excellence	Business Telephone (210) 536-4366		
Job-Site Address (street or physical location) c) OO-ALC/EMR 7274 Wardleigh Road	City: Hill AFB, UT 84056	State (abbrev.) UT	Zip 84056

SECTION III - CLIENT'S EVALUATION OF CORRECTIVE ACTION PERFORMED BY APPLICANT
(Please reference one specific job done during one specific time period.)

A. Show the project dates that the applicant participated in the corrective action activity.

From 01 Jun, 1995 To 01 Dec, 1997.

B. Which of the following corrective action activities were performed by the applicant on the above dates?

☐ LPST ☐ RCRA ☐ OSPRA ☒ CERCLA ☐ Chap. 26, TX WATER CODE

C. What type of corrective action service was done?

☒ Engineering ☐ Geology ☒ Hydrogeology ☒ Other (explain) Geotechnology

D. Please provide a detailed description of corrective action services (Phase II activities) performed by the applicant: The requested detailed description should be shown in six (6) Steps. Step 1: Locate and quantify the dense non-aqueous liquids (DNAPLS); Step 2: Perform Partitioning interwell tracer tests (PITTS) to determine the volume of DNAPL present; Step 3: Inject surfactant and isopropyl alcohol to solubilize DNAPL; Step 4: Extract micelle water, surfactant, alcohol, and TCE solubilized) and treat same through steam stripper; Step 5: Conduct a final PITT to determine how much DNAPL (product) had been removed and to determine saturation reduction; Step 6: Contractor transmitted Draft Technical Report and incorporated Air Force and

Continued in Section IV

E. Generally, was the activity completed to your satisfaction? ☒ Yes ☐ No If no, explain in Section IV.

F. Would you employ the applicant again for corrective action or other activities? ☒ Yes ☐ No If no, explain in Section IV.

G. Would you recommend (or have you recommended) the applicant for corrective action activities to your business associates or colleagues? ☒ Yes ☐ No If no, explain in Section IV.

H. Please indicate your general assessment of the applicant in the following categories:

Quality of Performance	☒ Execellent	☐ Good	☐ Poor	☐ Uncertain
Business Integrity	☐ Execellent	☒ Good	☐ Poor	☐ Uncertain

SECTION IV - ADDITIONAL INFORMATION (Identify applicable section number)

regulatory agency comments. The contractor then submitted the final Technical Report.

The prime contractor (now Duke Engineering) enabled the Air Force to locate, quantify, solubilize, and remove a large mass of DNAPL for the first time. The entire project received a complete endorsement by all regulatory agencies.

SECTION V - SIGNATURE

I, Sam A. Taffinder, do hereby attest that the above statements and information are true and correct to the best of my belief and knowledge.
Print or type name

Signature Sam A. Taffinder Date 20 Apr 98
Blue ink please

REF 68X NG 4/14/97 - J NGEA 4/4 MSP

68X

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. PAGE 1 OF 5

2. PROC INSTRUMENT ID NO. (PIIN)	3. SPIIN	4. EFFECTIVE DATE	5. REQUISITION/PURCHASE REQUEST PROJECT NO.	6. BCC/DMS RATING
F41624-95-C-8010	P00003	24 MAR 1997	FY7624-97-08138	DC-09

7. ISSUED BY CODE FA8900
DEPARTMENT OF THE AIR FORCE
AIR FORCE MATERIEL COMMAND
HUMAN SYSTEMS CENTER/PKV
3207 NORTH ROAD
BROOKS AFB, TX 78235-5363
Buyer: TOM MCLEAN, HSC/PKVBB
Phone: (210) 536-4490

8. ADMINISTERED BY (IF OTHER THAN BLOCK 7) CODE S4404A
DCMAO SAN ANTONIO
615 EAST HOUSTON STREET
P.O. BOX 1040
SAN ANTONIO, TX 78294-1040

DUPLICATE ORIGINAL

9. CONTRACTOR NAME AND ADDRESS CODE 0W330 FACILITY CODE
IF "9" FOR MULTIPLE FACILITIES SEE SECT "K"

INTERA INC.
9111 RESEARCH BOULEVARD
AUSTIN, TX 78758

COUNTY: TRAVIS
PHONE: (512) 425-2000

MAIL DATE
MAR 24 1997

10. SECURITY CLAS U

11. DISCOUNT FOR PROMPT PAYMENT

1 ST	%	DAYS	NET DAYS
2 ND	%	DAYS	OTHER IF '9'
3 RD	%	DAYS	SEE SECT 'E'

12. PURCHASE OFFICE POINT OF CONTACT
MOH/MOH/ME6

13. THIS BLOCK APPLIES ONLY TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in block 17. The hour and date specified for receipt of Offers ☐ is extended ☐ is not extended

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation, or as amended by on of the following methods:

(a) By signing and returning ______ copies of this amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE ISSUING OFFICE PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter provided such telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

14. THIS BLOCK APPLIES ONLY TO MODIFICATION OF CONTRACTS

☐ THIS CHANGE IS ISSUED PURSUANT TO ______
THE CHANGES SET FORTH HEREIN ARE MADE TO THE ABOVED NUMBERED CONTRACT/ORDER.

☐ THE ABOVE NUMBERED CONTRACT IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES (SUCH AS CHANGES IN PAYING OFFICE, APPROPRIATION DATA, ETC.) SET FORTH HEREIN.

☒ THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF CHAPTER 137, 10 USC 2304
IT MODIFIES THE ABOVE NUMBERED CONTRACT AS SET FORTH HEREIN.

☐ THIS MODIFICATION IS ISSUED PURSUANT TO ______

15 CONTRACT ADMINISTRATION DATA

A. KIND OF MOD	B. MOD ABST RECIPIENT ADP PT	C. DATE OF SIGNATURE MODIFICATION	D. CHANGE IN CONTRACT AMOUNT INCREASE (+) DECREASE (-)	E. LOSING PO/CAO ON TRANSFER	F. GAINING PO/CAO ON TRANSFER	G. SVC/AGENCY USE
C			+ $54,685.08			

16 ENTER ANY APPLICABLE CHANGES

A. PAY CODE	B. EFFECTIVE DATE OF AWARD	C. CONTRACT (1) TYPE (2) KIND	D. TYPE CONTR	E. SURV CRIT	F. SPL CONTR PROVISIONS	G. PAYING OFC CODE	H. DATE SIGNED	I. SECURITY (1) CLAS (2) DATE OF DD 254

17. REMARKS *(Except as provided herein, all items and conditions of the contract, as heretofore changed, remain unchanged and in full force and effect.)* SUBJECT: REVISE SOW, EXTEND SCHEDULE AND INCREASE CEILING.
PROJECT MANAGER: SAM TAFFINDER, AFCEE/ERT, BROOKS AFB TX 78235
PAYING OFFICE: (SC1024) DFAS-CO-JSB/GULF COAST DIVISION
P.O. BOX 182231
COLUMBUS, OH 43218-2231

18. ☐ CONTRACTOR/OFFEROR IS NOT REQUIRED TO SIGN THIS DOCUMENT
☒ CONTRACTOR/OFFEROR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 1 COPIES TO ISSUING OFFICE

19. CONTRACTOR/OFFEROR *(Signature of person authorized to sign)*
Patrick F. Malone

22. UNITED STATES OF AMERICA *(Signature of Contracting Officer)*
BY Thomas N. McLean Jr.

20. NAME AND TITLE OF SIGNER *(Type or print)*
PATRICK F. MALONE Contracts Manager

21. DATE SIGNED 3-18-97

23. NAME OF CONTRACTING OFFICER *(Type or print)*
THOMAS N. MCLEAN, JR.

24. DATE SIGNED 24 MAR 97

AFMC FORM 702, JUL 92 REPLACES AFSC FORM 702, AUG 84 WHICH IS OBSOLETE

1. The Statement of Work (SOW) dated 14 Mar 95 is deleted and the SOW dated 02 Dec 96 attached hereto is substituted in lieu thereof, the period of performance is extended from 30 Apr 97 to 02 Jun 97, and the total CEILING amount is increased by $54,685.08 from $1,018,047.00 to $1,072,732.08.

2. As a result of the above, the subject contract is more specifically modified as follows:

a. SECTION A - Cover Page - The total CEILING AMOUNT, Item Number 22, page 1, is increased by $54,685.08 from $1,018,047.00 to $1,072,732.08.

b. SECTION B - Supplies/Services - Section B is further amended as follows:

Item No	Supplies/Services		Quantity Purch Unit	Unit Price Total Item Amount
0001	CLIN CHANGE	sec class: U	1 LO	$ $

noun: SURFACTANT ENHANCED AQUIFER REMEDIATION

acrn: 9 nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-95-08172
FY7624-96-08874
FY7624-96-08A53
FY7624-97-08138
type contract: Y

000101 Info subCLIN sec class: U
noun: Funding - $798,047.00
acrn: AA nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-95-08172

000102 Info subCLIN sec class: U
noun: Funding - $220,000.00
acrn: AB nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-96-08874 $185,000.00
FY7624-96-08A53 $35,000.00

000103 Info subCLIN ESTABLISH sec class: U
noun: Funding - $54,695.08
acrn: AC nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-97-08138

b. SECTION B - Supplies/Services - CONTINUED

Item No	Supplies/Services	Quantity Purch Unit	Unit Price Total Item Amount
0002	CLIN CHANGE sec class: U	1 LO	$ $

noun: SUPPORT

acrn: 9 nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-95-08172
FY7624-96-08874
FY7624-96-08A53
FY7624-97-08138
type contract: Y

000201 Info subCLIN sec class: U
noun: Funding - Amount included in 000101
acrn: AA nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-95-08172

000202 Info subCLIN sec class: U
noun: Funding - Amount included in 000102
acrn: AB nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-96-08874
FY7624-96-08A53

000203 Info subCLIN ESTABLISH sec class: U
noun: Funding - Amount included in 000103
acrn: AC nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-97-08138

Item No	Supplies/Services	Quantity Purch Unit	Unit Price Total Item Amount
0003	CLIN CHANGE sec class: U	1 LO	NSP * NSP *

noun: DATA

acrn: 9 nsn: N
site codes cqa: D acp: D fob: D
pr/mipr data: FY7624-95-08172
FY7624-96-08874
FY7624-96-08A53
FY7624-97-08138
type contract: Y

(*) NSP = Not Separately Priced

3. SECTION C - Description/Specs/Work Statement - The SOW dated 14 Mar 95 is deleted and the SOW dated 02 Dec 96 attached hereto is substituted in lieu thereof and identified as Attachment 1.

4. SECTION F - Deliveries or Performance - Amend to extend the delivery schedule to "02 Jun 97".

Item No.	Supplies Schedule Data		Delivery Quantity	Schedule Date
0001	CLIN Del Sch CHANGE acrn: 9 Ship to: U	sec class: U	1 LO	97JUN02
0002	CLIN Del Sch CHANGE acrn: 9 Ship to: U	sec class: U	1 LO	97JUN02
0003	CLIN Del Sch CHANGE acrn: 9 Ship to: U	sec class: U	1 LO	97JUN02

5. SECTION G - Accounting and Classification Data - Amend as set forth below:

ACRN	Acct Class data	Appropriation/Lmt Subhead/CPN Recip DODAAD Supplemental Accounting Classification		Obligation Amount
AC	ACCOUNT ESTABLISH UNCLASSIFIED	5753400 305 3101 16080D 040000 59214 78008F	F28500 660700	$54,685.08

pr/mipr data: FY7624-97-08138 PR COMPLETE

For Information Only: ACRN "9" includes the following:

ACRN	AMOUNT	OBLIGATING CONTRACT ACTION
AA	$ 798,047.00	Basic
AB	$ 185,000.00	P00001
AB	$ 35,000.00	P00002
AC	$ 54,685.08	P00003
TOTAL:	$1,072,732.08	

FINANCE OFFICER: Pay funds on ACRN AA first, then pay funds on ACRN AC, and then pay funds on ACRB AB.

6. This modification constitutes complete and final settlement for all claims arising under and relating to the changes herein.

7. SECTION J - List of Attachments:

IDENTIFIER	TITLE	NR OF PAGES
ATCH #1	Statement of Work, Demonstration of Cost and Time Savings Using Surfactant Enhanced Aquifer Remediation for DNAPLS at USAF Installations dated 02 Dec 96	8

SLIP#: 1438

To Team Chief: Mr Sam Taffinder, ERT, 4366

DATE 03-Jun-98

CONTRACT NUMBER/DELIVERY ORDER NUMBER: F41624-95-C-8010 / 0

BILLING PERIOD: 19-Jun-95 -- 31-Jul-97

Return to Data Specialist:
Completed Invoice Routing Slip
Signed and dated Invoice
Actual Expenditure Tracking Report

INVOICE NUMBER: 1 thru 14 SHIPMENT/VOUCHER NO:

THE FOLLOWING INVOICE IS FORWARDED FOR YOUR REVIEW AND ACTION. PLEASE APPROVE/DISAPPROVE AND FORWARD TO THE DATA SPECIALIST INDICATED BELOW:

SF1034 (PUBLIC VOUCHER, 4 DAY SUSPENSE)

APPROVAL DATE: 09 Jun 98 DISAPPROVAL DATE: ______________

DATA SPECIALIST: Ingra Haynes, MSI/SRD, 6317

COR: Mr Sam Taffinder, ERT, 4366
Contract Manager: FAILE
Contract Owner: vacant

Administrator: Ms Grace Elizalde, PKVB
CO: Mr John Caporal, PKVBB, 2394
Buyer: vacant

ACTUAL EXPENDITURES TRACKING REPORT

RUN DATE: 03-JUN-98
RUN TIME: 11:06

COST FOR PERIOD: 19-JUN-95 - 31-JUL-97
CONTRACTOR: INTERA INC.
CONTRACT/ORDER: F41624-95-C-8010/0
TC: TAFFINDER, SAM

TOTAL ORDER CEILING: 1072732.08

REPORT PERIOD START	END	COST CATEGORY	FUNDS USED THIS PERIOD	FUNDS USED TO DATE	PERCENT USED	FUNDS REMAINING (Fixed Fee Included)
19-JUN-95	31-OCT-95	LABOR	72082.50	72082.50	6.7195	
		ODC OTHER	26230.44	26230.44	2.4452	
		SUBTOTAL	98312.94	98312.94	9.1647	974419.14
01-NOV-95	30-NOV-95	LABOR	12373.04	84455.54	7.8729	
		ODC OTHER	34384.85	60615.29	5.6506	
		SUBTOTAL	46757.89	145070.83	13.5235	927661.25
01-DEC-95	31-DEC-95	LABOR	13339.08	97794.62	9.1164	
		ODC OTHER	37979.81	98595.10	9.1910	
		SUBTOTAL	51318.89	196389.72	18.3074	876342.36
01-JAN-96	31-JAN-96	LABOR	18979.85	116774.47	10.8857	
		ODC OTHER	8748.09	107343.19	10.0065	
		SUBTOTAL	27727.94	224117.66	20.8922	848614.42
01-FEB-96	29-FEB-96	LABOR	25429.58	142204.05	13.2563	
		ODC OTHER	7957.54	115300.73	10.7483	
		SUBTOTAL	33387.12	257504.78	24.0046	815227.30
01-MAR-96	31-MAR-96	LABOR	22342.88	164546.93	15.3391	
		ODC OTHER	17401.56	132702.29	12.3705	
		SUBTOTAL	39744.44	297249.22	27.7096	775482.86
01-APR-96	31-JUL-96	LABOR	156271.80	320818.73	29.9067	
		ODC OTHER	207438.12	340140.41	31.7079	
		SUBTOTAL	363709.92	660959.14	61.6146	411772.94
01-AUG-96	31-AUG-96	LABOR	62970.58	383789.31	35.7768	
		ODC OTHER	99586.44	439726.85	40.9913	
		SUBTOTAL	162557.02	823516.16	76.7681	249215.92
01-SEP-96	30-SEP-96	LABOR	30968.38	414757.69	38.6637	
		ODC OTHER	127365.36	567092.21	52.8643	
		SUBTOTAL	158333.74	981849.90	91.5280	90882.18

ACTUAL EXPENDITURES TRACKING REPORT

RUN DATE: 03-JUN-98
RUN TIME: 11:06

COST FOR PERIOD: 19-JUN-95 - 31-JUL-97
CONTRACTOR: INTERA INC.
CONTRACT/ORDER: F41624-95-C-8010/0
TC: TAFFINDER, SAM

TOTAL ORDER CEILING: 1072732.08

REPORT PERIOD START	END	COST CATEGORY	FUNDS USED THIS PERIOD	FUNDS USED TO DATE	PERCENT USED	FUNDS REMAINING (Fixed Fee Included)
01-OCT-96	31-OCT-96	LABOR	3328.09	418085.78	38.9739	
		ODC OTHER	7469.85	574562.06	53.5606	
		SUBTOTAL	10797.94	992647.84	92.5346	80084.24
01-NOV-96	31-MAR-97	LABOR	11152.02	429237.80	40.0135	
		ODC OTHER	27301.19	601863.25	56.1056	
		SUBTOTAL	38453.21	1031101.05	96.1192	41631.03
01-APR-97	30-APR-97	LABOR	7978.39	437216.19	40.7573	
		ODC OTHER	165.08	602028.33	56.1210	
		SUBTOTAL	8143.47	1039244.52	96.8783	33487.56
01-MAY-97	30-JUN-97	LABOR	30028.19	467244.38	43.5565	
		ODC OTHER	61.88	602090.21	56.1268	
		SUBTOTAL	30090.07	1069334.59	99.6833	3397.49
01-JUL-97	31-JUL-97	LABOR	1304.41	468548.79	43.6781	
		ODC OTHER	31.82	602122.03	56.1298	
		SUBTOTAL	1336.23	1070670.82	99.8079	2061.26
GRAND TOTAL			1070670.82	1070670.82	99.8079	2061.26

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 1

DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION …tment of the Air Force …rce Material Command Human Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	DATE VOUCHER PREPARED 11/30/95 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624–95–D8172	SCHEDULE NO. PAID BY

PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO / WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	6/19/95 to 10/31/95	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				98,312.94

…e continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

…ent: …sional _ Complete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______	
	By:[2] Bob Hardy		Amount verified, correct for	
	Title Auditor, DCAA		*(Signature or Initials)*	

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98	Sam [signature]	COR
(Date)	(Authorized Certifying Officer)[2]	(Title)

Accounting Classification

PAID BY	Check Number / On Account of U.S. Treasury	Check Number / On *(Name of Bank)*	
	Cash / Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630 NSN 7540-00-634-420…

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL CONTINUATION SHEET	VOUCHER NO. 1 SCHEDULE NO. SHEET NO. 1
	Department of the Air Force, Brooks AFB, Texas	

INTERA Inc.
6850 Austin Center Blvd., Suite 300
Austin, Texas 78731

Contract No. F41624-95-C-8010

Contract Ceiling: $798,047.00

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty. Hours	Unit Price Cost: Current Cost	Per: Hours	Amount: Cumulative Cost
	6/19/95 to 10/31/95	Labor	1069.0	72,082.50	1069.0	72,082.50
	6/19/95 to 10/31/95	Other Direct Costs		26,230.44		26,230.44
		Total		98,312.94		98,312.94

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B. Craven — Project Manager
Signature — Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Received 09 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL	VOUCHER NO. 2

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED 12/29/95	SCHEDULE NO.
rtment of the Air Force rce Material Command an Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624-95-D8172	PAID BY

PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER

SHIPPED FROM	TO	WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	11/1/95 to 11/30/95	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				46,757.89

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

nent: visional nplete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		*(Signature or Initials)*

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 *(Date)* — Sam [signature] *(Authorized Certifying Officer)*[2] — COR *(Title)*

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency

[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.

[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630

NSN 7540-00-634-4206

PRIVACY ACT STATEMENT

The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 2

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	11/1/95 to 11/30/95	Labor	186.5	12,373.04	1,255.50	84,455.54
	11/1/95 to 11/30/95	Other Direct Costs		34,384.85		60,615.29
		Total		46,757.89		145,070.83

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul T. [signature] — Signature

Project Manager — Title

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL	VOUCHER NO. 3

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED 1/17/96	SCHEDULE NO.
nent of the Air Force e Material Command Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624-95-D8172	PAID BY

PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO / WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	12/1/95 to 12/31/95	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				51,318.89

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

ent: ional lete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		(*Signature or Initials*)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (*Date*) — [signature] (*Authorized Certifying Officer*)[2] — COR (*Title*)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On (*Name of Bank*)
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1988-0-491-248/20630 NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Sta:.:ard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 3

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	12/1/95 to 12/31/95	Labor	201.5	13,339.08	1,457.00	97,794.62
	12/1/95 to 12/31/95	Other Direct Costs		37,979.81		98,595.10
		Total		51,318.89		196,389.72

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Crane — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-S26 (7103)

Standard Form 1034
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

VOUCHER NO. 4 Received 09 Jun 98

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION
epartment of the Air Force
r Force Material Command
man Systems Center/PKVBB
05 9th Street
Brooks AFB, Texas 782335-5353

DATE VOUCHER PREPARED: 2/21/96

CONTRACT NUMBER AND DATE: F41624-95-C-8010

REQUISITION NUMBER & DATE: FY7624-95-D8172

SCHEDULE NO.

PAID BY

PAYEE'S NAME AND ADDRESS:
INTERA Inc.
6850 Austin Center Boulevard
Suite 300
Austin, Texas 78731

DATE INVOICE RECEIVED

DISCOUNT TERMS

PAYEE'S ACCOUNT NUMBER

SHIPPED FROM | TO | WEIGHT | GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (Either description, item number of contract or Federal supply schedule, and other information deemed necessary)	Quantity	Unit Price Cost	Unit Price Per	Amount
	1/1/96 to 1/31/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				27,727.94

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

Payment:
Provisional
omplete
artial
_ Final
_ Progress
_ Advance

Approved For: Provisional Payment subject to Later Audit
= $

Exchange Rate = $1.00

Differences ______

By:² Bob Hardy

Title Auditor, DCAA

Amount verified, correct for

(Signature or Initials)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) — [signature] (Authorized Certifying Officer)² — COR (Title)

Accounting Classification

PAID BY: Check Number — On Account of U.S. Treasury — Check Number — On (Name of Bank)

Cash — Date — Payee³ $

Per

Title

¹When stated in foreign currency, insert name of currency
²If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
³When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630

NSN 7540-00-634-42

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 4

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	1/1/96 to 1/31/96	Labor	299.5	18,979.85	1,756.50	116,774.47
	1/1/96 to 1/31/96	Other Direct Costs		8,748.09		107,343.19
		Total		27,727.94		224,117.66

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B. Cramer — Signature

Project Manager — Title

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL	VOUCHER NO. 5

DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED 12/21/96	SCHEDULE NO.
...rtment of the Air Force ...orce Material Command ...man Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624–95–D8172	PAID BY

PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO / WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	2/1/96 to 2/29/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				33,387.12

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

...ment: ...visional _ Complete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______	
	By:[2] Bob Hardy		Amount verified, correct for	
	Title Auditor, DCAA		*(Signature or Initials)*	

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) — [signature] *(Authorized Certifying Officer)*[2] — COR *(Title)*

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1988-0-491-248/20630 NSN 7540-00-634-420...

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

·Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 5

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (Either description, item number of contract or Federal supply schedule, and other information deemed necessary)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010		Contract Ceiling:	$798,047.00	
			Hours	Current Cost	Hours	Cumulative Cost
	2/1/96 to 2/29/96	Labor	391.5	25,429.58	2,148.00	142,204.05
	2/1/96 to 2/29/96	Other Direct Costs		7,957.54		115,300.73
		Total		33,387.12		257,504.78

RTIFICATION

tify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made ne Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Crane — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL	VOUCHER NO. 6
S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION rtment of the Air Force orce Material Command nan Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	DATE VOUCHER PREPARED 4/23/96 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624-95-D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	3/1/96 to 3/31/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				39,744.44

se continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

ent: visional omplete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		*(Signature or Initials)*

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) — Sam N. Laffinder (Authorized Certifying Officer)[2] — CO (Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630

NSN 7540-00-634-420

PRIVACY ACT STATEMENT

The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 6

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	31/96 to 3/31/96	Labor	338.5	22,342.88	2,486.50	164,546.93
	3/1/96 to 3/31/96	Other Direct Costs		17,401.56		132,702.29
		Total		39,744.44		297,249.22

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Crown — Signature

Project Manager — Title

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 7
U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION Department of the Air Force Air Force Material Command Human Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	DATE VOUCHER PREPARED 09/11/96 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624–95–D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	04/01/96 to 07/31/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				363,709.92

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

Payment:	Approved For	Exchange Rate	Differences
Provisional _ Complete _ Partial _ Final _ Progress _ Advance	Provisional Payment subject to Later Audit = $	= $1.00	
	By:² Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		*(Signature or Initials)*

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) Sam [signature] (Authorized Certifying Officer)² COR (Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee³ $	

¹When stated in foreign currency, insert name of currency
²If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
³When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630

NSN 7540-00-634-42

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL** CONTINUATION SHEET	VOUCHER NO. 7 SCHEDULE NO. SHEET NO. 1
	Department of the Air Force, Brooks AFB, Texas	

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	04/01/96 to 07/31/96	Labor	2,607.0	156,271.80	5,093.50	320,818.73
	04/01/96 to 07/31/96	Other Direct Costs		207,438.12		340,140.41
		Total		363,709.92		660,959.14

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B. Crane — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-S26 (7103)

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 8
U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION partment of the Air Force Force Material Command Human Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	DATE VOUCHER PREPARED 09/24/96 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624–95–D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	08/01/96 to 08/31/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				162,557.02

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

Payment:	Approved For	Exchange Rate	Differences ______
Provisional _ Complete _ Partial _ Final _ Progress _ Advance	Provisional Payment subject to Later Audit = $	= $1.00	
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		*(Signature or Initials)*

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (*Date*) — Sam H. Laffender (*Authorized Certifying Officer*)[2] — COR (*Title*)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On (*Name of Bank*)
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630 NSN 7540-00-634-420

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 8

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amoun
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$798,047.00		
			Hours	Current Cost	Hours	Cumula Cost
	08/01/96 to 08/31/96	Labor	1,162.5	62,970.58	6,256.0	383,789
	08/01/96 to 08/31/96	Other Direct Costs		99,586.44		439,726
		Total		162,557.02		823,516

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments ma by the Contractor except as otherwise authorized in the payments of the contract and property reflect the work performed.

Paul B Crau _______________ Signature

Project Manager _______________ Title

Received 24 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 9

·PARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED 11/04/96	SCHEDULE NO.
·ent of the Air Force A· ·e Material Command Human Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	CONTRACT NUMBER AND DATE F41624-95-C-8010	PAID BY
	REQUISITION NUMBER & DATE FY7624-95-D8172	

PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	09/01/96 to 09/30/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				158,333.74

(·ntinuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

·: X ·visional _ Complete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______	
	By:² Bob Hardy		Amount verified, correct for	
	Title Auditor, DCAA		*(Signature or Initials)*	

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 *(Date)* Sam A. Daffinder *(Authorized Certifying Officer)*² COR *(Title)*

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number On *(Name of Bank)*
	Cash	Date	Payee³ $

¹When stated in foreign currency, insert name of currency
²If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
³When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1988-0-491-248/20830

NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 9

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:			$798,047.00
			Hours	Current Cost	Hours	Cumulative Cost
	09/01/96 to 09/30/96	Labor	483.5	30,968.38	6516.5	414,757.69
				127,365.36		567,092.21
	09/01/96 to 09/30/96	Other Direct Costs				
				158,333.74		981,849.90
		Total				

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Crau — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-S26 (7103)

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 10

DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION Department of the Air Force Air Force Material Command Human Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	DATE VOUCHER PREPARED 11/21/96 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624–95–D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 6850 Austin Center Boulevard Suite 300 Austin, Texas 78731	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO	WEIGHT / GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	10/01/96 to 10/31/96	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				10,797.94

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

Payment:	Approved For	Exchange Rate	Differences ______
X Provisional _ Complete _ Partial _ Final _ Progress _ Advance	Provisional Payment subject to Later Audit = $	= $1.00	
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		(*Signature or Initials*)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (*Date*) — Lomd. Zaffinder (*Authorized Certifying Officer*)[2] — COR (*Title*)

Accounting Classification

PAID BY				
	Check Number	On Account of U.S. Treasury	Check Number	On (*Name of Bank*)
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630 NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

YFM

Standard Form 1035 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL** CONTINUATION SHEET	VOUCHER NO. 10 SCHEDULE NO. SHEET NO. 1
	Department of the Air Force, Brooks AFB, Texas	

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 6850 Austin Center Blvd., Suite 300 Austin, Texas 78731		Contract No. F41624-95-C-8010	Contract Ceiling:	$1,018,047.00		
			Hours	Current Cost	Hours	Cumulative Cost
	10/01/96 to 10/31/96	Labor	52.5	3,328.09	6569.0	418,085.78
	10/01/96 to 10/31/96	Other Direct Costs		7,469.85		573,386.40
		Total		10,797.94		991,472.18

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Crain   Project Manager

Signature   Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Received 09 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 11 03
DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION ...nt of the Air Force A... Material Command H... ystems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	DATE VOUCHER PREPARED 4/28/97 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624-95-D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 9111 Research Blvd Austin, Texas 78758	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	11/01/96 to 03/31/97	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				$38,453.21

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

...t: ...nal ...te _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______	
	By:[2] Bob Hardy		Amount verified, correct for	
	Title Auditor, DCAA		*(Signature or Initials)*	

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date)   [signature] (Authorized Certifying Officer)[2]   COR (Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
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Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20830   NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 11

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (Either description, item number of contract or Federal supply schedule, and other information deemed necessary)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 9111 Research Blvd. Austin, Texas 78758		Contract No. F41624-95-C-8010	Contract Ceiling:	$1,072,732.08		
			Hours	Current Cost	Hours	Cumulative Cost
	11/01/96 to 01/31/97	Labor	112.50	11,152.02	6681.50	429,237.80
	11/01/96 to 03/31/97	Other Direct Costs		27,301.19		~~600,687.59~~ 601,863.25
		Total		38,453.21		~~1,029,925.39~~ 1,031,101.05

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B Craven — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Total Contract Ceiling $1,072,732 24 Mar 97

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	**PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL**	VOUCHER NO. 12

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED	SCHEDULE NO.
...ent of the Air Force ...: Material Command h... Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335–5353	5/13/97	
	CONTRACT NUMBER AND DATE F41624-95-C-8010	PAID BY
	REQUISITION NUMBER & DATE FY7624–95–D8172	

PAYEE'S NAME AND ADDRESS	INTERA Inc. 9111 Research Blvd Austin, Texas 78758	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER

SHIPPED FROM	TO	WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Quantity	Unit Price Cost	Unit Price Per	Amount
	4/1/97 to 4/30/97	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				$8,143.47

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

...t: ...ional ...ete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		*(Signature or Initials)*

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) — Sam D. Laffisiden (Authorized Certifying Officer)[2] — COR (Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
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Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1966-0-491-248/20630

NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

Standard Form 1035
Revised January 1980
Department of the Treasury
TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 12

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 9111 Research Blvd. Austin, Texas 78758		Contract No. F41624-95-C-8010	Contract Ceiling:	$1,072,732.08		
			Hours	Current Cost	Hours	Cumulative Cost
	4/1/97 to 4/30 /97	Labor	94.5	7,978.39	6794.0	437,216.19
	4/1/97 to 4/30/97	Other Direct Costs		165.08		~~600,852.66~~ 602,028.33
		Total		8,143.47		~~1,038,068.85~~ 1,039,244.52

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and property reflect the work performed.

Paul B Crane
Signature

Project Manager
Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Standard Form 1034
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

VOUCHER NO. 13

Received 04 Aug

06-02

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION	DATE VOUCHER PREPARED	SCHEDULE NO.
nent of the Air Force e Material Command Systems Center/PKVBB b. th Street Brooks AFB, Texas 782335-5353	7/25/97	
	CONTRACT NUMBER AND DATE F41624-95-C-8010	PAID BY
	REQUISITION NUMBER & DATE FY7624-95-D8172	

PAYEE'S NAME AND ADDRESS	INTERA Inc. 9111 Research Blvd Austin, Texas 78758	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER

SHIPPED FROM	TO	WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (Either description, item number of contract or Federal supply schedule, and other information deemed necessary)	Quantity	Unit Price Cost	Unit Price Per	Amount
	51/97 to 6/30/97	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				$30,090.07

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

ent: sional lete al _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______
	By:[2] Bob Hardy		Amount verified, correct for
	Title Auditor, DCAA		(Signature or Initials)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98	Sam A. Laffinder	COR
(Date)	(Authorized Certifying Officer)	(Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On (Name of Bank)
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
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Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20630 NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
The information requested on this form is required under the revisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

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TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 13

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 9111 Research Blvd. Austin, Texas 78758		Contract No. F41624-95-C-8010	Contract Ceiling:			$1,072,732.08
			Hours	Current Cost	Hours	Cumulative Cost
	5/1/97 to 6/30\97	Labor	620.5	30,028.19	6888.5	467,244.38
	5/1/97 to 6/30/97	Other Direct Costs		61.88		602,090.21
		Total		30,090.07		1,069,334.59

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and property reflect the work performed.

Paul B. Crane — Signature

Project Manager — Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

Received 04 Jun 98

Standard Form 1034 Revised January 1980 Department of the Treasury 1 TFRM 4-2000	PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL	VOUCHER NO. 14 07.73)

S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION artment of the Air Force Force Material Command uman Systems Center/PKVBB 8005 9th Street Brooks AFB, Texas 782335-5353	DATE VOUCHER PREPARED 8/12/97 CONTRACT NUMBER AND DATE F41624-95-C-8010 REQUISITION NUMBER & DATE FY7624-95-D8172	SCHEDULE NO. PAID BY
PAYEE'S NAME AND ADDRESS	INTERA Inc. 9111 Research Blvd Austin, Texas 78758	DATE INVOICE RECEIVED DISCOUNT TERMS PAYEE'S ACCOUNT NUMBER
SHIPPED FROM	TO / WEIGHT	GOVERNMENT B/L NUMBER

Number and Date of Order	Date of Delivery or Service	Articles or Services (*Either description, item number of contract or Federal supply schedule, and other information deemed necessary*)	Quantity	Unit Price Cost	Unit Price Per	Amount
	7/1/97 TO 7/31/97	For details, see Statement of Cost and Continuation Sheet SF1035 Cost Reimbursement - Provisional Payment Time & Materials				$1,336.23

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL

ment: ovisional _ Complete _ Partial _ Final _ Progress _ Advance	Approved For Provisional Payment subject to Later Audit = $	Exchange Rate = $1.00	Differences ______	
	By:[2] Bob Hardy		Amount verified, correct for	
	Title Auditor, DCAA		*(Signature or Initials)*	

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

09 Jun 98 (Date) — Sam ... (Authorized Certifying Officer)[2] — CO (Title)

Accounting Classification

PAID BY	Check Number	On Account of U.S. Treasury	Check Number	On *(Name of Bank)*
	Cash	Date	Payee[3] $	

[1]When stated in foreign currency, insert name of currency
[2]If the ability to certify and authority to approve are combined in one person, one signature only is necessary otherwise the approving officer will sign in the space provided, over his official title.
[3]When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary," or "Treasurer", as the case may be.

Per

Title

U.S. GOVERNMENT PRINTING OFFICE 1986-0-491-248/20830

NSN 7540-00-634-4206

PRIVACY ACT STATEMENT
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Standard Form 1035
Revised January 1980
Department of the Treasury
1 TFRM 4-2000

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

CONTINUATION SHEET

VOUCHER NO. 14

SCHEDULE NO.

SHEET NO. 1

Department of the Air Force, Brooks AFB, Texas

Number and Date of Order	Date of Delivery or Service	Articles or Services *(Either description, item number of contract or Federal supply schedule, and other information deemed necessary)*	Qty.	Unit Price Cost	Unit Price Per	Amount
INTERA Inc. 9111 Research Blvd. Austin, Texas 78758		Contract No. F41624-95-C-8010	Contract Ceiling:		$1,072,732.08	
			Hours	Current Cost	Hours	Cumulative Cost
	7/1/97 to 7/31/97	Labor	19.5	1,304.41	6908.0	468,548.79
	7/1/97 to 7/31/97	Other Direct Costs		31.82		602,122.03
		Total		1,336.23		1,070,670.82

CERTIFICATION

I certify that this invoice is correct and in accordance with the terms of the contract and that the costs included herein have been incurred, represent payments made by the Contractor except as otherwise authorized in the payments of the contract and properly reflect the work performed.

Paul B [signature] Project Manager

Signature Title

U.S. Government Printing Office: 1981 0 - 341-526 (7103)

PERFORMANCE INFORMATION

PROJECT 1

A. Offeror Name (Company / Division)

Duke Engineering & Services, Inc. / Federal Group

B. Program Title

Characterization & Remediation of DNAPLs at Operable Unit 2, Hill Air Force Base, Utah

C. Contract Specifics

1. Contract Number: F41624-95-C-8010 CAGE Code: 0W330
2. Contract Type: Estimated cost; fixed fee
3. Period of Performance: 6/95 – 11/97
4. Original Contract Value: $798,047
5. Current Contract Value: $1,072,732.08

   Discussion of Potential Difference: Because this contract involved the development and demonstration of previously untested innovative characterization and remediation technologies, unforeseen additions to the scope of work and changed site conditions resulted in higher-than-estimated costs.

6. Was contract awarded under current name?
   Yes _____ No __X__ Previous company name: INTERA Inc.

D. Brief description of effort as __X___ Prime or __ X __ Subcontractor

The above contract information, as well as that contained in Item E, represents our first task at Hill AFB, completed for the Air Force Center for Environmental Excellence (AFCEE). To date we have completed, or are currently performing, work on four tasks valued at nearly $2,000,000. This work has been, or will be, accomplished through four different contracts (a prime contract with AFCEE and subcontracts with Rice University, URS Greiner, Inc., and Radian International). Because we are conducting simultaneous tasks, our work at Hill AFB involves many of the same technical and management challenges encountered while performing on a multiple-task order program.

At Hill AFB, remediation of chlorinated solvents such as TCE, PCE, and TCA, also known as dense non-aqueous phase liquids (DNAPLs), represents a significant challenge to the base's environmental restoration efforts. Because DNAPLs are relatively insoluble in water, once in the subsurface they serve as a continuous source of contamination as they slowly dissolve into surrounding ground water. The removal of this contaminant "source" is critical to implementing a cost- and time-effective remedial strategy.

> Project contaminants relevant to those identified in Sect. 2.3 of the SOW include:
>
> - Trichloroethene (TCE)
> - 1,1,1-Trichloroethane (1,1,1-TCA)
> - Tetrachloroethylene (PCE)

Until recently, no satisfactory methods have existed for quantifying and subsequently removing all—or nearly all—of the DNAPL from a contaminated aquifer. However, over the past three years, DE&S has successfully demonstrated two technologies—partitioning interwell tracer tests (PITTs) and surfactant-enhanced aquifer remediation (SEAR)—at Hill AFB's Operable Unit 2 (OU2) that are capable of accomplishing these goals. Brief descriptions of our work at Hill are provided below.

Demonstration of Surfactant-Enhanced Aquifer Remediation of Chlorinated Solvent DNAPL at OU2—The addition of surfactants to a remediation system offers the possibility of removing nearly all of the DNAPL in a contaminated aquifer by solubilization and/or mobilization of the liquid source. In 1996, DE&S conducted a successful application of SEAR at OU2 through a prime contract with AFCEE. Prior to flooding the test area with surfactant, an innovative characterization technique known as the PITT was performed to provide an accurate determination of the volume of DNAPL present in the aquifer test zone. A surfactant flood was then used to remove all of the DNAPL from the test zone. A final PITT, which DE&S staff conducted to verify the performance of the SEAR flood, showed that the average DNAPL saturation had been reduced from 4% (by volume) to 0.04% and that 99% of the DNAPL (341 of the 346 gallons) had been removed.

Demonstration of a Surfactant/Foam Process for Aquifer Remediation at OU2—The first-ever field application of a surfactant/foam process for remediating DNAPLs was successfully conducted at OU2 during the spring of 1997 by DE&S under contract to Rice University. The main objective of the surfactant/foam technology is to improve the performance of the SEAR process in a heterogeneous aquifer by providing a more uniform sweep of the formation. Again, DE&S used the PITT technology and design to accurately determine the quantity of residual DNAPL in the test zone prior to the surfactant/foam flood. During the flood, air was injected to produce a foam that effectively "blocked" more permeable zones and allowed the surfactant to also enter less permeable zones. A final PITT showed that the surfactant/foam flood reduced residual DNAPL saturation over the entire test zone from 0.26% to 0.03%. This innovative approach can significantly reduce the cost of DNAPL source removal in heterogeneous aquifers.

DNAPL Source Zone Delineation at OU2—To establish the basis for comparing the technical and economic feasibility of remedial alternatives being considered for OU2 (i.e., soil vapor extraction or SVE, SEAR, and steam flooding), an accurate measure of DNAPL volume and extent is needed across the entire shallow alluvial aquifer. The PITT method is an integral part of an approach to accomplish this objective, and DE&S is presently under subcontract to URS Greiner to implement this characterization program. To date, we have completed the first three phases of a five phase program, and we are currently performing hydraulic test analysis and numerical modeling to assist in determining the final PITT designs. The final phase, the implementation of four large-scale PITTs, is scheduled to begin in May 1998.

Expedited Remediation of the "Griffith" DNAPL Pool Near OU2—DE&S is currently preparing to remediate the DNAPL pool located outside of the containment wall at the north end of OU2, under subcontract to Radian International. Discovered by DE&S in the fall of 1997, the "Griffith" pool is estimated to contain between 5,000 and 10,000 gallons of DNAPL. For this remediation approach, DE&S will design and install a system of injection and extraction wells to pump as much free-phase DNAPL out of the pool as possible. DE&S will then design and conduct a SEAR flood to remove the remaining DNAPL. This phase will consist of a PITT to measure the volume of DNAPL remaining in the aquifer, a surfactant flood to remove this volume, and a final PITT conducted as a performance assessment of the remedial effort to confirm clean-up to the desired level.

E. Completion Date

1. Original contractual date: 4/30/97
2. Current schedule: Completed 11/28/97
3. Estimated date of completion: N/A
4. How many times changed: Two

Primary causes of change: Additions/changes to the Scope of Work

F. Primary government or equivalent points of contact

1. Program Manager: Mr. Sam Taffinder (210) 536-4366
HQ AFCEE/ERT, 3207 North Rd., Brooks AFB, TX 78235-5363

Dr. Jon Ginn, Hill AFB Env. Mgmt. Directorate (801) 775-6894
OO-ALC/EMR, 7276 Wardleigh Rd., Hill AFB, UT 84056-5127

2. PCO: Mr. Tom McLean, Dept. of the Air Force (210) 536-4490
Air Force Materiel Command, Human Systems Center / PKV
3207 North Road, Brooks Air Force Base, TX 78235-5363

3. ACO: N/A

G. Project characteristics considered unique

- *Innovative DNAPL source zone characterization and remediation technologies.* At Hill, DE&S has conducted the most successful SEAR demonstrations to date. We have also demonstrated the effectiveness of PITTs to accurately characterize the volume and distribution of NAPL in the subsurface. Knowing the quantity and distribution of DNAPL is critical to designing and implementing an effective remedial system.
- *Improved characterization techniques.* Accurate characterization of site contaminants is critical to designing and constructing an efficient remedial system. At Hill, DE&S has utilized unique methods and tools for: preserving VOC soil samples for accurate measurement of different DNAPL phases; insuring that sample recoveries during drilling are maximized; determining DNAPL saturations from core samples using the NAPLANAL numerical code; and performing pneumatic slug tests in large diameter wells. All of these methods are directly applicable at other Hill sites and can lead to the design and implementation of more effective remedial systems.

H. Project experience relevant to Section M evaluation areas

Factor 1 – Mission Capability

DE&S has developed an integrated approach to dealing with NAPLs (which include both DNAPLs and light non-aqueous phase liquids or LNAPLs) using PITTs and SEAR that can readily be adapted to a variety of sites at Hill. Our initial work at Hill AFB demonstrated that these technologies offer a viable means of accurately determining the quantity of residual NAPL and subsequently removing nearly all (typically around 99%) of the contamination from the subsurface. Our follow-on work is focusing on the full-scale application of these technologies to alleviate some of the most difficult remedial challenges at Hill.

Remedial Action Design and Construction—Although to date our work at Hill has focused on demonstrating these technologies at the pilot-scale level, DE&S possesses the broad design and construction capabilities necessary to implement these, and other, technologies at full-scale. Our work at Hill has involved the design and construction of remedial system components including: injection/extraction wells to optimize removal of DNAPL and ensure hydraulic control; batch and continuous injectate mixing and delivery systems; automated flow control and monitoring systems; automatic VOC sampling system; and associated piping systems. DE&S has used sophisticated numerical models when appropriate to assist in PITT and SEAR flood design to determine injection and extraction rates, duration of various stages of the remedial process, and quantities and concentrations of injectates.

"In all of our dealings with [DE&S] they have shown a high degree of technical expertise. Reports have been submitted on time and have been of the highest quality. Their employees have been very conscientious and easy to work with. . . [We] highly recommend them at other Federal Facilities.

—Comment from Steve Hicken
Remediation Manager at Hill AFB

Remedial Systems O&M—DE&S's experience at Hill involves O&M of complex PITT and SEAR systems. Activities performed by DE&S staff include: chemical injectate mixing operations, including QA/QC sampling and control; fluid control and metering of the injection and extraction operations, including manual flow rate measurements and adjustments; aqueous sampling; well field effluent control and management; operation and servicing of pumps, tanks, air compressors, flow control valves and meters, and data acquisition systems; water-level and water-quality measurements; maintenance of field logs and project records; servicing, cleaning, and repairing secondary containment and sumps, and transferring liquid waste; site safety management, air monitoring, and maintenance of site safety records.

Subfactor Three: Personnel Plan—Staffing positions for our work at Hill are shown below:

Position	***No. of Personnel***	***Responsibilities***
Program Manager	1	Overall technical/financial control of project; corporate resource commitment
Project Manager	2	Technical cost and schedule control; regulatory interaction; reporting; subcontractor management; equipment procurement
Site Manager	1	Management of all field operations; health and safety; QA/QC
Hydrogeologist	4	Oversight during drilling and sampling programs; shift supervision during PITT and SEAR injection and extraction operations
Geologist	2	PITT and SEAR injection and extraction operations
Chemist	2	On-site sample analyses
Environmental Eng.	2	Design of injection/extraction well arrays, PITTs, and SEAR floods
Field Technician	2	Installation, O&M of injection/extraction systems and chemical mixing equipment

Subcontractors were selected based on past performance, cost, familiarity with site-specific requirements, and the ability to provide unique services. Subcontractors have included: the University of Texas at Austin for tracer and surfactant screening and selection; RC Exploration for drilling; Star Analytical and On-Site for laboratory analyses; Applied Research Associates for cone penetrometer test surveying; and Radian International for O&M of the Source Recovery System (SRS). Although no contract or subcontract for our work at Hill AFB has specified small business utilization goals, DE&S has used small, minority-, and woman-owned businesses to provide services that include laboratory analyses (Star Analytical) and drilling (RC Exploration). To date, approximately 10% of our total contract value has been spent with small businesses.

Subfactor Four: Breadth of Experience—DE&S's work at Hill AFB demonstrates our experience in a number of areas that are relevant to the subject RAC for environmental construction/ services. The matrix included on pages 3 and 4 of the Introduction summarizes the types of work relevant to this procurement (from SOW Sect. 2.2) that were accomplished on this project.

Based on our performance at Hill, the Air Force has direct evidence that DE&S has the requisite skills and experience to successfully provide services under a RAC. From a technical standpoint, the remedial action services we have performed as part of the innovative technology demonstration program provide directly relevant experience with the geologic and hydrogeologic conditions as well as some of the most common and challenging contaminants found at Hill AFB.

Project Management and Performance—Through our work at Hill, DE&S has also demonstrated the ability to manage simultaneous tasks under stringent schedules and deadlines. To successfully complete our tasks at Hill AFB, we have mobilized the appropriate staff, from highly experienced technical experts to field supervisors and technicians from multiple DE&S offices. In addition, by responding to the interests of all stakeholders including regulators, the Air Force, and Hill AFB personnel, we have been able to gain quick acceptance of task work plans. The successful coordination of our work to accommodate other ongoing technology demonstration projects and work activities is evidence of our flexibility and desire to contribute to the overall environmental efforts at Hill AFB.

DE&S managers have maintained good communications throughout our work at Hill AFB by means of scheduled and impromptu meetings, progress summaries, monthly reports, and through the use of e-mail and phone calls. Our ability to effectively communicate is demonstrated through our successful coordination of field operations with Hill AFB personnel, regulators, two separate A/E primes, three university research teams, two commercial technology demonstrations, one construction contractor, and a host of other subcontractors.

> *"One of the best contractor reports I have read. I was very impressed with the clarity and organization of the document."*
>
> —Comment from Steve Hicken, Remediation Manager at Hill AFB

We have developed site-specific health and safety and project QA/QC plans prior to performing work at Hill AFB. We document our work in high quality reports that clearly support the actions taken and the benefits to the project and the environment. At Hill AFB, our technical personnel responsible for performing most of the field activities have also been responsible for writing reports, reviewing data and drawings, directing quality control, and submitting draft reports for senior review. This serves to minimize errors and/or misinterpretation of field data while increasing the project manager's accountability for his or her work product. All of our clients at Hill AFB have been completed satisfied with the quality of our deliverables.

Schedule Control—Our project managers use software including Primavera and Microsoft Project to prepare project schedules, balance resources, and forecast activities. This allows us to easily track project activities, assign personnel, and adjust the performance timeline for tasks. All of our work at Hill AFB has been completed on schedule.

DE&S's flexibility and desire to work effectively with other participants in the Hill AFB program has resulted in no disruption of scheduled program activities. Despite working on relatively new and innovative technologies, our performance has consistently been of the highest technical quality. We have been successful in demonstrating characterization and remediation technologies that will yield lower overall clean-up costs at Hill AFB.

Factor 4 – Cost/Price

DE&S has worked hard at Hill to track project costs because it is important to both our clients and us. All of our tasks have been completed on, or under, budget with the exception of our first technology demonstration for AFCEE. Because this task involved one of the first field applications of PITTs and SEAR at a DNAPL-contaminated site, unforeseen changes to the scope of work were required to complete this project. Since that time however, improved estimating and costing procedures have resulted in all tasks being completed within the prescribed budgets. Cost estimates for these tasks have been developed based on our experience with similar projects and contractor quotes for services and supplies.

I. Project Key Personnel Identified for this Procurement

Project Key Personnel	*Proposed Position for this Procurement*
Hans Meinardus — Site Manager	Project Manager — Subsurface RA
Stacy Griffith — Project Hydrogeologist	Project Hydrogeologist
Lisa Rottinghaus — Project Geologist	Project Geologist
Sonny Casaus — Field Technician	Field Technician

J. Problems Encountered

Problem	*Resolution*
Management: Increased costs associated with expanding scope of work under AFCEE contract	Extensive interaction between DE&S's Program Manager and AFCEE contracting and technical representatives to discuss requirements for additional scope of work elements and to provide justification for scope changes. DE&S management implemented more stringent cost controls to ensure that future minor scope changes could be accommodated within the existing budget.
Management: Inadequate tracking and inventorying of equipment purchased by DE&S on behalf of the government.	Our contracts manager met with the Property Administrator of the Technical Assessment Group of the Defense Contract Management Command. Our current tracking process was evaluated and improvements were implemented.
Technical: Difficulty in moving fluids through injection/ extraction systems during winter.	Installation of tank heaters and winterizing surface piping systems.
Technical: Periodic diverting of effluent to adjust SRS performance during remedial activities.	Developed agreement with Frac Tanks, Inc. to bring large temporary storage tanks for the well field effluent on site within a two hours notice.
Technical: Periodic power outages during remedial activities.	Ensured availability of emergency power generators (rented or supplied by the base) to keep the remediation demonstrations or field tests operating with minimum down time.

CHARACTERIZATION OF A DNAPL ZONE WITH PARTITIONING INTERWELL TRACER TESTS

Hans W. Meinardus, Richard E. Jackson, Minquan Jin, and John T. Londergan (Duke Engineering and Services, Inc, Austin, Texas)
Sam Taffinder (USAF Center for Environmental Excellence, Brooks AFB, Texas)
Jon S. Ginn (Environmental Management Directorate, Hill AFB, Utah)

ABSTRACT: During 1996 and 1997, five separate partitioning interwell tracer tests (PITTs) were conducted as part of two separate surfactant-enhanced aquifer remediation (SEAR) demonstrations targeting DNAPL (primarily TCE) at Operable Unit 2 (OU2), Hill Air Force Base, Utah. These PITTs were used as a DNAPL characterization tool to accurately determine: 1.) the total aquifer volume swept; 2.) the total amount of DNAPL present in the swept aquifer volume; and, 3.) the average residual saturation present. PITTs were conducted before and after each SEAR demonstration to provide remediation performance assessments and were hydraulically controlled without using sheetpile walls. The successful implementation of field-scale PITTs required an engineering design strategy using conventional characterization activities, laboratory studies, and UTCHEM modeling. The volume sampled by each PITT was on the order of an average of 6500 ft^3 (14,000 gallon pore volume). Tracer recoveries ranged from 79% to 92%, indicating that, within experimental error, all of the injected tracers were recovered.. The method of temporal moments was used to analyze each PITT, and the resulting DNAPL volume estimates were in close agreement with other measurements (e.g. SEAR DNAPL recoveries, and core data estimates). Thus, in sandy alluvium, PITTs are very accurate estimators of DNAPL volumes, and provide an excellent characterization and performance assessment tool for DNAPL remediation efforts. Based on the success of these PITTs, the USAF is currently conducting large-scale PITTs to characterize the entire DNAPL source zone at OU2.

INTRODUCTION

Operable Unit 2 (OU2), located on the northeastern boundary of Hill Air Force Base in Utah, was used from 1967 to 1975 to dispose of unknown quantities of chlorinated organic solvents from degreasing operations. These dense non-aqueous phase liquids (DNAPLs), primarily trichloroethene (TCE), were placed into at least two unlined disposal trenches underlain by an alluvial sand aquifer. This shallow unconfined aquifer consists of a heterogeneous mixture of sand and gravel, and is contained in a buried paleochannel eroded into thick clay deposits. A large volume of DNAPL remains in the subsurface as a mobile phase pooled in the topographic lows of the clay aquiclude, and as an immobile or "residual" phase retained as ganglia by capillary forces in the aquifer's pore spaces.

Two variations of surfactant-enhanced aquifer remediation (SEAR) for DNAPL removal were recently demonstrated at OU2. During the summer of 1996, a demonstration of surfactant-enhanced aquifer remediation (SEAR) funded by the US Air

Force Center for Environmental Excellence (AFCEE) was conducted in a portion of the buried paleochannel. In the spring of 1997, a demonstration of a surfactant/foam process, an advanced form of SEAR for heterogeneous alluvial aquifers, was undertaken. This demonstration, funded by the Advanced Applied Technology Demonstration Facility (AATDF), was conducted in a test area adjacent to the AFCEE SEAR project area. As part of these surfactant flood demonstrations, five separate partitioning interwell tracer tests (PITTs) were conducted to characterize the DNAPL zone in the test areas.

The Partitioning Interwell Tracer Test (PITT). Studies of residual DNAPL distribution in heterogeneous aquifer materials indicate that cores are unlikely to either locate or provide reliable estimates of DNAPL volumes of at the field scale. This is true because the representative elementary volume of residual DNAPL appears to be much larger than that provided by cores (see Mayer and Miller, 1992). The PITT, developed at the University of Texas by Dr. G. A. Pope from a predecessor first used by the oil industry, allows the detection and estimation of DNAPL volumes in the subsurface over meaningful distances at the field scale.

The PITT involves the injection of a suite of tracers in one or more wells and subsequent extraction from other wells in a well field. Conservative (i.e., nonpartitioning) tracers pass unretarded through the DNAPL zone, whereas the partitioning tracers are retarded due to their partitioning into and out of the DNAPL. In the unsaturated zone of an aquifer, the tracers employed are gases, whereas liquid tracers (e.g., alcohols) are used in the saturated zone. The chromatographic separation of the tracers due to this partitioning is used to measure the volume of DNAPL in the interwell zone.

Objectives. During the AFCEE SEAR demonstration, three separate PITTs were conducted demonstration area, and two PITTs were conducted in the AATDF demonstration area as part of the surfactant/foam flood. These saturated zone PITTs were used as a DNAPL characterization tool able to accurately determine: 1.) the total aquifer volume swept during the tests; 2.) the total amount of DNAPL present in the aquifer volume swept by the tracers; and, 3.) the average residual saturation present in the swept volume (the volume tracer flowed through), and its spatial distribution. The main objective of the both the AFCEE and AATDF PITTs was to provide a remediation performance assessment by determining the volume of DNAPL in the swept volume before and after conducting a surfactant flood. Another objective was to hydraulically control each PITT without using sheetpile walls.

PITT DESIGN

The successful implementation of field scale PITTs requires an engineering design strategy utilizing conventional site characterization activities, laboratory studies, and careful systematic modeling. The drilling of reconnaissance borings and wells provided alluvium samples for initial residual saturation estimates and for laboratory experiments to assess candidate partitioning tracers. The information from field and laboratory studies were then incorporated into the UTCHEM simulator employed to design each PITT.

Site Characterization and Well Field Installation. The first three PITTs were conducted in the AFCEE SEAR well field consisting of three injection wells and three extraction wells in a 3 x 3 line-drive geometry and one hydraulic control (injection) well (HC-1) to prevent the upgradient flow of tracers and surfactant, and one interwell monitor well (see Figure 1). The distance between injectors (SB-2, 3 and 4) and extractors (U2-1, SB-1 and 5) was 20 ft (6.1 m); the distance between individual injectors and individual extractors was 10 ft (3 m); the water table depth was approximately 25 ft (7.6 m) below ground surface; and there was a 4-ft (1.2 m) thick zone of free-phase and residual DNAPL approximately 45 ft (13.7 m) below ground surface. The screened intervals of the injectors and extractors were completed in this DNAPL zone and extended above it.

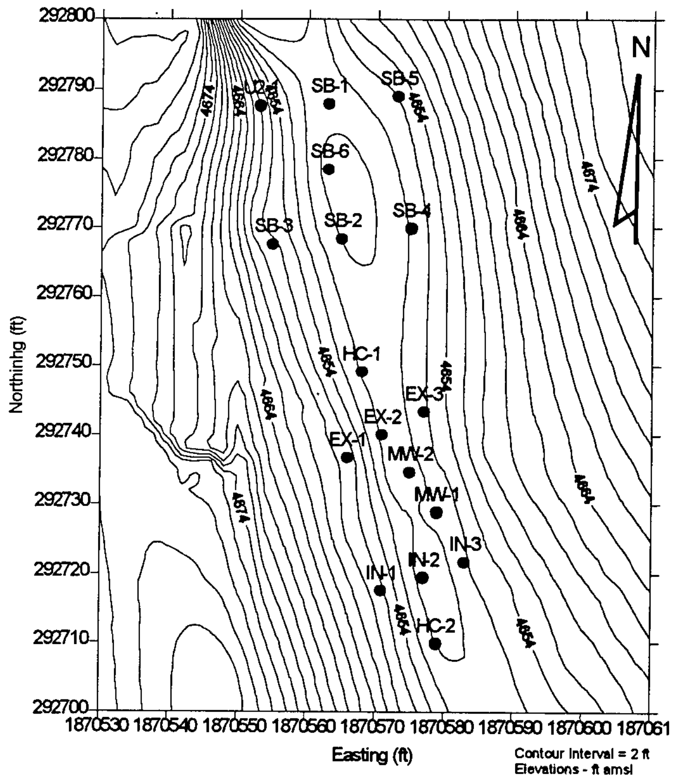

Figure 1. AFCEE SEAR and AATDF Well Fields

Two PITTs were also conducted in the AATDF Surfactant/Foam demonstration area. This well field was installed south of the AFCEE area, spanned the width of the buried channel, and was approximately 45 ft (13.7 m) deep at the channel centerline (see Figure 1). Similar to the AFCEE well field, three injection and three extraction wells were completed in a 20 ft (6.1 m) long line drive pattern (the outermost wells were about 12 ft (3.7 m) apart). Two multilevel monitoring wells were located between the injection and extraction wells, and two hydraulic control wells were located about 10 ft (3 m) behind the central injector and central extractor respectively. Core samples indicated that the DNAPL was confined to the bottom 1.2 meters (4 feet) of the channel and was present in smaller quantities (local saturations of 2%-14%) than in the AFCEE SEAR demonstration area.

Once the wells were logged, installed, developed, and surveyed, an aquifer testing program was conducted: 1.) to provide hydraulic data specific to the aquifer volume to be tested; 2.) to determine sustainable injection and extraction rates; and, 3.) to provide data to calibrate the numerical PITT design model. Since PITTs require establishing a forced-gradient flow-field and use ground water as a carrier to transport tracers across the zone of interest, a conservative interwell tracer test (CITT) was conducted in each well field. CITTs provide empirical data for PITT design, contribute greatly to the understanding of the hydrogeologic system, and afford the opportunity to refine tracer test procedures. Bromide and chloride were used as conservative tracers.

Laboratory Studies. In order to use partitioning tracers to determine residual DNAPL volumes, an accurate measurement of the partitioning coefficient of each tracer used is required. It is also important to choose tracers with partitioning coefficients that will be sufficiently retarded by the DNAPL present to maximize the accuracy of the PITT. A more detailed discussion on the selection criteria for partitioning tracers can be found in Jin et. al.(1995). Experiments were carried out to measure the partition coefficients of several long chained aliphatic alcohols with OU2 DNAPL under static or equilibrium conditions.

Once the partitioning coefficients were determined, partitioning tracer column studies were conducted with OU2 DNAPL and sediment. First, several partitioning tracer experiments were performed in uncontaminated alluvium to determine if there was any retardation due to organic material in the sediment. Retardation factor measurements for the selected tracers ranged between 0.999 and 1.028, well within the ± 0.035 experimental accuracy of determining tracer retardations (Dwarakanath, 1997), and so retardation or adsorption of partitioning alcohol tracers by the alluvium was determined to be negligible. Next, partitioning tracers were used to determine known residual Hill DNAPL saturations in contaminated sediment. Independent estimates of the amount of residual DNAPL present were also calculated using both a mass balance (weighing the column) and a volume balance (measuring the amount of DNAPL retained in the column). The partitioning tracer estimates of residual DNAPL saturation agreed extremely well with volume and mass balance estimates, with a standard deviation of under 5% between the estimates.

UTCHEM Modeling. UTCHEM simulations were used to finalize the design of the PITTs. UTCHEM is a multiphase, multicomponent, three-dimensional chemical compositional finite-difference simulator originally developed to model surfactant enhanced oil recovery and modified for SEAR applications (Delshad et. al., 1996). The models incorporated the three-dimensional structure of the buried channel formed by the aquiclude, hydraulic information obtained during the site characterizations, and a distribution of DNAPL based on sediment sample data. The simulation predictions were used to determine the flow rates for the test, the concentration and duration of the tracer slugs, and the composition of the PITT effluent. The model results were also used to establish the length of the PITTs, and to formulate the PITT sampling plan.

PITT IMPLEMENTATION

Before initiating a PITT, source water was injected while pumping at the extraction wells to established a steady-state flow field. Then a solution of conservative and partitioning tracers mixed in source water was injected, typically for 0.5 days. A 5 to 7 day water flood to recover both the conservative and partitioning tracers followed the tracer injection. Constant injection and extraction rates were maintained throughout each of the PITTs, with total injection rates at 6 to 8 gpm (3.8E-4 to 5E-4 m3/s), and total extraction of 9 to 11 gpm (5.7E-4 to 6.9E-4 m3/s). Over production at the extraction wells was balanced with potable water injection into hydraulic control wells. Pressure transducers were used to automatically monitor water for the duration of each PITT.

In theory, only one partitioning and one nonpartitioning tracer are required to determine the amount of DNAPL present in the target zone. In practice, a suite of partitioning tracers is used to account for potential variations in the amount of DNAPL present. Table 1 lists some of the tracers used for the PITTs, their partitioning coefficients, the injected tracer concentrations, and the amounts recovered. The swept volumes listed on Table 1 (e.g. an average of 6500 ft^3 (184 m^3) for the AFCEE PITTs), illustrate the difference between characterizing a DNAPL zone with a PITT as opposed to a limited number of borehole samples, with a typical volume of 3.5E-2 ft^3 (1E-5 m^3) for each. Taking tracer recovery measurement errors into account, it can be concluded that all of the injected chemicals were recovered during each of the PITTs. The tracer recoveries helped support the conclusion that hydraulic control of the injected fluids in the swept volume with no mechanical containment was demonstrated during both projects.

Table 1. Summary of PITTs

Tracer	Partition Coefficient	Injected Concentration (mg/L)	Tracer Recovery (%)
AFCEE PITT1 (Swept Volume = 12,940 gals)			
Isopropanol	0.1	1,678	86
1-Pentanol	3.9	1,248	89
2-Ethyl-1-butanol	12.5	1,227	92
AFCEE PITT2 (Swept Volume = 14,150 gals)			
Isopropanol	0.1	1,572	89
1-Pentanol	3.9	1,247	90
2-Ethyl-1-butanol	12.5	1,144	92
AFCEE PITT3 (Swept Volume = 15,360 gals)			
1-Propanol	0.1	854	90
1-Hexanol	30.2	798	83
1-Heptanol	140.5	606	89
AATDF PITT1 (Swept Volume = 8,180 gals)			
Isopropanol	0.1	1090	83
1-Heptanol	140.5	555	85
AATDF PITT2 (Swept Volume = 8,310 gals)			
1-Propanol	0.1	881	84
n-Octanol	200	147	79

RESULTS AND ANALYSIS

All of tracer curves acquired were analyzed using the method of temporal moments (see Jin et. al., 1995). An example of the tracer concentration history for the central extraction/injection well pair (SB-1/SB-2) during the initial AFCEE PITT is presented in Figure 2. The partitioning tracers are clearly retarded with respect to the conservative tracer, indicating that substantial quantities of DNAPL are present in the aquifer volume between these two wells. The PITT estimated the residual DNAPL amount in the test area prior SEAR to be 346 gallons. As shown in Figure 3, the PITT3 tracer curves obtained at this well pair after the AFCEE SEAR flood overlie each other, indicating that there is little or no DNAPL left to retard the partitioning tracers. The amount of DNAPL left in swept volume was estimated to be about 5 gallons, corresponding to an average saturation of 0.03%. The SEAR PITTs indicated that the total amount of DNAPL recovered was 341 gallons. Based on well effluent data, the amount of DNAPL recovered was 494 gallons, while the effluent treatment system recorded recovering 363 gallons. Similar results were obtained for the AATDF project, including a close match with detailed soil core data. Based on the success of these PITTs, the USAF is currently conducting large-scale PITTs to characterize the entire DNAPL source zone at OU2.

ACKNOWLEDGMENTS

AFCEE funded the SEAR demonstration conducted by DE&S (formerly INTERA, Inc.) in collaboration with the Center for Petroleum and Geosystems Engineering at the UT-Austin and Radian International, LLC. UT-Austin funded the design of the surfactant floods and PITTs. The AFCEE project manager was Mr. Sam Taffinder.

The AATDF, a research facility funded by the Army Corps of Engineers, (WES) through Rice University funded the surfactant/foam demonstration. The AATDF Project Manager was Dr. Stephanie Fiorenza. Dr.'s George Hirasaki and Clarence Miller of the Chemical Engineering Department of Rice University led the demonstration team. Dr. B. Wade and Dr. G. Pope of the UT-Austin provided technical and logistical support. DE&S managed the field operations, designed, conducted, and analyzed the PITTs, and assisted in the flood design. Radian International LLC provided flood effluent treatment and field support. Hill AFB graciously hosted both demonstrations and provided extensive logistical support. We thank Rob Stites, U.S. EPA Region VIII, and Mo Slam and Duane Mortensen at the Utah Department of Environmental Quality, for their input, and support.

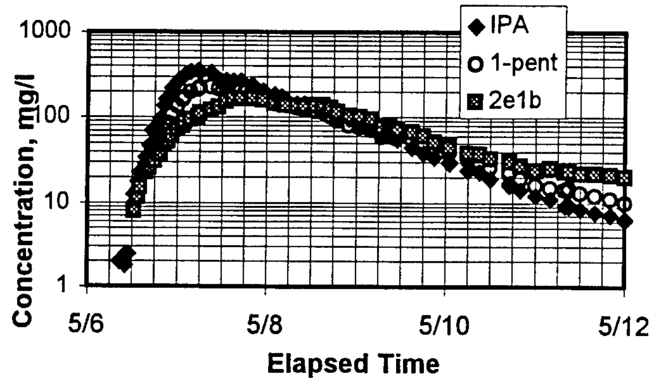

Figure 2. AFCEE PITT1 - Wells SB-1/SB-2

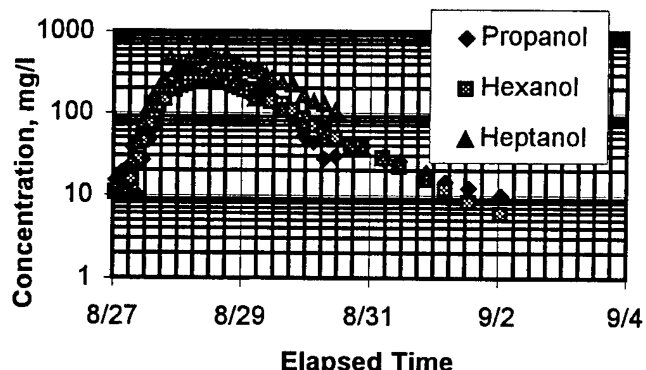

Figure 3. AFCEE PITT3 - Wells SB-1/SB-2

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Jin, M., M. Delshad, V. Dwarakanath, D.C. McKinney, G.A. Pope, K. Sepehrnoori, C.E. Tilburg, and R.E. Jackson. 1995. "Partitioning Tracer Test For Detection, Estimation And Remediation Performance Assessment Of Subsurface Nonaqueous Phase Liquids," *Water Resources Research*, 31(5), 1201-1211.

Mayer, A.S., and C.T. Miller. 1992. "The Influence Of Porous Media Characteristics And Measurement Scale On Pore-Scale Distributions Of Residual Nonaqueous Phase Liquids," *J. Cont.. Hydrology*, 11, 189-213.

CHARACTERIZATION OF A DNAPL ZONE WITH PARTITIONING INTERWELL TRACER TESTS

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Two variations of surfactant-enhanced aquifer remediation (SEAR) were recently demonstrated at OU2. As part of these surfactant flood demonstrations, five separate partitioning interwell tracer tests (PITTs) were conducted. These PITTs represent a DNAPL characterization tool able to accurately determine: 1.) the total aquifer volume swept during the tests; 2.) the total amount of DNAPL present in the aquifer volume swept by the tracers; and, 3.) the average residual saturation present in the swept volume, and its spatial distribution. The successful implementation of field-scale PITTs requires an engineering design strategy using careful and systematic modeling. First, conventional site characterization activities such as drilling, sampling and hydraulic testing programs were conducted, including conservative tracer tests. The resulting data, along with laboratory studies conducted at UT Austin, were incorporated into a geosystem model which integrated stratigraphic, hydraulic and contaminant data. UTCHEM, a 3-D multiphase multi-component compositional simulator was then employed to design the PITTs for each SEAR demonstration.

The PITTs were conducted before and after each SEAR demonstration to provide remediation performance assessments. They were hydraulically controlled, without the use of sheetpile walls, and the volume sampled by each PITT was on the order of an average of 6500 ft^3 (14,000 gallon pore volume). The injected tracers recoveries ranged from 79% to 92%, implying that, within experimental error, all injected tracers were recovered. The method of temporal moments was used to analyze each PITT, and the resulting DNAPL volume estimates were in close agreement with other measurements (e.g. DNAPL recovered during each SEAR, and estimates based on core data). Thus, in sandy alluvium, PITTs are very accurate estimators of DNAPL volumes, and provide an excellent characterization and performance assessment tool for DNAPL remediation efforts. Based on the success of these PITTs, the USAF is currently conducting large-scale PITTs to characterize the entire DNAPL source zone at OU2.

To: SAM TAFFINDER@ERT
From: Jacqueline Avvakoumides <javvakou@duke-energy.com>
Cc:
Bcc:
Subject: Permission to Present AFCEE Work
tachment: abstract.doc
Date: 02/25/1998 8:51 AM

(with abstract this time!)

Dear Sam,

I am in the process of submitting an abstract on an overview of all the site characterization/remediation work at Hill AFB to be presented at the August 18-20 Tri-Service Environmental Technology Workshop in San Diego, CA. I've attached the abstract for your review and comment.

Could you please give me some guidance on the process whereby I should obtain permission to present the AFCEE work? Hans Meinardus gave me a copy of an email from Gilberto Dominguez that lists the following requirements:

1. Name, title and organization (as appropriate) of originator 2. Title of article, paper, speech, script, abstract, etc.
3. Statement of where, when and how the information is to be released and the organization sponsoring the occasion
4. Suspense date required by originator, if earlier than date of presentation or publication
5. A statement or certification that the information is unclassified, does not violate a contractor's proprietary rights and is suitable for public release
6. Signed or initialed notation by author or speaker indicating approval of the text

Could you tell me if this is what I need to provide - and also to whom I should provide it?

Many thanks for your help,

Jacqui Avvakoumides
Duke Engineering & Services
(512)425-2077

h

CHARACTERIZATION AND REMEDIATION OF A DNAPL CONTAMINATED AQUIFER AT OU2, HILL AFB, UTAH

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Duke Engineering and Services, Inc. 9111 Research Blvd., Austin, TX 78758
Gary A. Pope
University of Texas at Austin, TX 78712
Jon S. Ginn
Environmental Management Directorate, 7274 Wardleigh Road, Hill AFB, Utah 84056
G. Chris Stotler
URS Greiner, Inc., 1099 18th Street, Suite 700, Denver, CO 80202
Sam A. Taffinder
Headquarters AFCEE, 3207 North Road Bldg. 532, Brooks AFB, Texas, 78235

Operable Unit 2 (OU2), at Hill Air Force Base, Utah, was used from 1967 to 1975 to dispose of unknown quantities of chlorinated organic solvents from degreasing operations. These dense non-aqueous phase liquids (DNAPLs)., primarily trichloroethene (TCE), were placed into two unlined disposal trenches underlain by an alluvial aquifer. The shallow unconfined aquifer is composed of a heterogeneous mixture of sand and gravel, and is contained in a paleo-channel eroded into thick clay deposits. A large volume of DNAPL remains in the subsurface as a mobile phase pooled in the topographic lows of the clay aquiclude, and as an immobile or "residual" phase retained as ganglia by capillary forces in the aquifer's pore spaces.

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Two separate successful demonstrations of surfactant-enhanced aquifer remediation [SEAR] targeting DNAPL have been completed at OU2. The design and implementation of these surfactant floods depended on accurate characterization of a portion of the DNAPL source zone. Conventional site characterization activities included drilling, logging, sampling, and hydraulic testing. Vertical profiles of residual saturations were obtained from chemical analyses of soil cores using partitioning theory as implemented in the code NAPLANAL. Pneumatic slug tests and injection/extraction tests were used to determine aquifer properties. Conservative tracers were conducted to determine aquifer transport properties.

As part of the surfactant demonstration projects, five partitioning interwell tracer tests (PITTs) have been conducted at OU2. PITTs represent a characterization tool that accurately determines the total amount of DNAPL present in the aquifer volume swept by the tracers, as well as an accurate estimate of the average residual saturation. At OU2, PITTs were used to characterize the demonstration zones before and after the surfactant demonstrations to provide a performance measure for the remediation efforts.

Subsequently, the USAF has initiated a DNAPL Source Zone Delineation Project at OU2. The focus of this project is to use large-scale PITTs to determine the total volume and extent of DNAPL contamination in the source zone. PITT results will be used in a technical and cost comparison of remedial alternatives, i.e., soil vapor extraction, surfactant-enhanced aquifer remediation, and steam flooding. The resulting information will be used in the design of the technology to be used to remediate the remaining DNAPL.

Geophysical and cone penetrometer surveys of the site were used to design the new PITT well field. Once installed, the well field were tested to determine the hydraulic properties of the aquifer. Samples of the alluvium were used in laboratory experiments to assess the suitability of partitioning tracers and the potential for DNAPL mobilization during water floods. UTCHEM simulations will be employed to design water floods and the PITTs. The water floods will mobilize and remove as much free-phase DNAPL as possible via the extraction well arrays in the well field. After free-phase DNAPL recovery has ceased, conservative and partitioning tracers will be added to the waterflood. The resulting information will then be incorporated into a geosystem model which defines hydrogeological properties and DNAPL distribution in the alluvium.

BOOZ·ALLEN & HAMILTON INC.

300 CONVENT STREET • SUITE 1250 • SAN ANTONIO, TEXAS 78205

December 17, 1997
B-09006-0326-4011-0001001

Mr. Sam Taffinder
Technology Transfer Division
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Subject: AFCEE Contract No. F41624-94-C-8013, TDA # ERD ERT 97-01-001, Adequacy of the Contractor's Responses to Comments on the Draft Final Report for the Demonstration of Surfactant-Enhanced Aquifer Remediation of Dense Nonaqueous-Phase Liquids, Hill AFB, Utah

Deliverable #: DT970101.57

Dear Mr. Taffinder:

Booz·Allen & Hamilton Inc. reviewed the contractor's responses to comments on the subject document. The contractor's responses were adequate, and no further questions or comments were identified.

If you have any questions or would like to discuss this document further, please contact me at (210) 244-4218.

Sincerely,

Robert Edwards

BOOZ·ALLEN & HAMILTON INC.

for
Marc D. Gill, Ph.D., P.E.
Associate

cc: AFCEE/ERC (Lt. Col. Gregory E. Seely)
AFCEE/ERC (Mr. Stephen A. Gagliano)
AFCEE/ERT (Maj. Edward Marchand)
HSC/PKV (Ms. Mary Habib)
BA&H File

FAX

DATE: November 30, 1997

TO: Mr. Sam Taffinder
AFCEE HQ

PHONE: 210-536-43[illegible]
FAX: 210-536-43[illegible]

FROM: Paul B. Cravens

PHONE: 512-425-2013

RE: Final Report Comments Response Schedule

CC:

Number of pages including cover sheet: 1

Comments:

Sam, I got your voice mail Friday am but was not able to return it in time to catch you. I have all the sections to our response now that are of a technical nature and will collate them tomorrow (Monday) as I travel. I'm on the road for the next two weeks but will check voice mail each evening. I'll fax this to you as soon as I can, possibly tomorrow night.

Pablo

DE&S
Duke Engineering & Services

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

Technology Transfer Division (AFCEE/ERT)

Sam A. Taffinder, Innovative Technology Project Manager

3207 North Road Brooks AFB, Texas 78235-5363

Office Phone: (210) 536-4366 DSN 240-4366; Fax # (210) 536-4330 DSN 240-4330

To: Mr. Paul Cravens	**FAX #: (512) 425-2099**	**Phone #: (512) 425-2000**
Date: Tues, 25 Nov 97	**Time: 1100 hours**	**No. of Pages** (incl. cover): 8

Message:

Dear Paul,

This memo is a follow-up to your fax letter dated 21 Nov 97 concerning responses to Air Force comments and the delivery of the Final Report under Contract # F41624-95-C-8010. First I recommend that you send nothing to Mr. Thomas McClean regarding the delivery of the Final Report. Final Reports often are transmitted one or more months after the period of performance is over. However, I do need to know what is your firm projected date to transmit the Final Report.

I consider your responses to Comments 38-40 to be acceptable. However, your response to Air Force Comment #36 is not acceptable. According to paragraphs 1.3 and 3.3.5, the requested information is well within the scope of these two paragraphs regarding the evaluation of the SEAR system for treatment of NAPLs (para 1.3) and for costing full scale treatment of effluent concerning capitol and treatment costs (para 3.3.5). If you disagree, please let me know immediately.

Additionally, I will need sufficient copies of the Final Technical Report to send four (4) copies outside AFCEE. If you have any questions, I will be at Brooks only today and until tomorrow noon. Thanks.

FAX

DATE: December 1, 1997

TO: Mr. Sam Taffinder
AFCEE HQ

PHONE: 210-536-4363
FAX: 210-536-4330

FROM: Paul B. Cravens

PHONE: 512-425-2013

RE: Response to Comment #36 Contract No. F41624-95-C-8010

CC:

Number of pages including cover sheet: 1

Comments:

Sam,

I'm in receipt of your fax where, in part, you mentioned that our response to the initial comment #36 was not acceptable. I've added language to the text (see my latest response letter) that discusses options for addressing the BOD/COD issues that an IWTP might have with the effluent from the plant. In this I mention that the economy of each option will have to be studied on a case by case basis. Specifically, I gave the example that bio-treatment might not be economical due to the large storage capacities that might be required. I did not address the cost of such technologies, since that would be very site specific and speculative at best (not to mention some of the technologies are still being developed).

Does this address Comment #36 to your satisfaction?

Pablo

See Page 5

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Fax 512 425-2099

December 1, 1997

Delivered by Facsimile

Mr. Sam Taffinder
AFCEE HQ
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Re: AFCEE SEAR Demonstration
Hill AFB, Utah
Contract No. F41624-95-C-8010

Dear Mr. Taffinder:

Thank you for your letter of November 3, 1997 in which you forwarded comments to our correspondence of October 17, 1997. This correspondence provided you with additional information on the Draft Final Report for the above referenced project.

In your letter you requested a partial response to comments by November 18, 1997, specifically addressing original comments numbered 36, 38, and 39. We provided a response by fax on that date, forwarded by U.S. Mail November 10th.

This letter constitutes a response to the new comments provided with your letter of November 3rd. Due to the relatively few numbers of comments, we will respond to them within the body of this letter. Any significant changes to the text of the draft report are attached for your review.

As you know, INTERA Inc. is now doing business as Duke Engineering & Services, Inc., although INTERA remains a corporate entity. For ease of review, we will self-reference throughout this correspondence as INTERA Inc. or INTERA.

Contracting Officer's Representative (COR's) Comments

Comment #1: *When will the final results be available so INTERA can finish Section 6.4.3 and transmit for AF review.*

A completed Section 6.4.3 is provided as an attachment to this letter.

Comment #2: *My comments to this response also ties into your new paragraph 7.4.3, "Predicted Impacts on the IWTP". Simply stated, Hill AFB is far more concerned about the BOD and COD demands of the steam stripper effluent after surfactant injection than the TCE concentrations. Although INTERA was not directly tasked to measure BOD, COD, TSS, etc.*

of the effluent, these measurements were taken during our field demonstration. Therefore, the Final Report should have some general discussion regarding how their concerns over BOD, COD, etc. should be addressed. For example, hill AFB is considering additional holding and equalization tanks, pulsed releases of the effluent, the permitting of the steam stripper, and the monitoring of compounds of interest.

We have added verbiage to Section 8.4.1.2 that provides a general discussion of the IWTP BOD/COD issue. This section has been renamed "Addressing Surfactant and Cosolvent in the Effluent". This discussion includes a listing of responses that might be studied and considered by Hill. A copy of the new text is attached for your review. OK

For the edification of a reviewer of this correspondence that was not associated with the work, INTERA did not conduct BOD, COD, or TDS/TSS testing during the AFCEE SEAR demonstration. INTERA did provide process information to the IWTP so they could evaluate the impact the effluent would have on their operations. They agreed that the IWTP could receive the effluent and not cause the plant to exceed their discharge regulatory limits. Hill AFB IWTP likely ran tests for BOD and COD. INTERA did not request, receive, nor evaluate copies of these test results as this was not called for in the Scope of Work nor in the approved Work Plan. INTERA did run and evaluate such tests during a later SEAR demonstration at this site, but for a different client.

Comment #3: *This section (7.4.3) seems to be irrelevant without a comparison of predicted impacts to actual impacts. You already have a fairly good discussion of Treatment Challenges in Section 8.4.1 of the Draft Final. If you enlarged this section to include a general discussion of BOD and COD concerns, I think this would be sufficient as long as this discussion included paragraphs 8.4.1.3 and 8.4.1.4. The BOD to organic ratio is most likely 1:1.5.*

As mentioned in our response to Comment #3, we have developed additional text to discuss options for addressing increased BOD/COD at the IWTP in Section 8.4.1.2. We understand that section 7.4.3 does not have as much substance as might be desired. However, since the Scope of Work and approved Work Plan did not call for tracking these parameters at the IWTP, we do not have data that would support more concrete discussions. With the additional verbiage concerning treatment options in Section 8.4.1.2 and the general discussion provided in Section 7.4.3, we have provided the most complete discussion of this issue that is possible, considering the information available and called for in the scope of work and approved Work Plan. We have retained Subsections 8.4.1.3 and 8.4.1.4 within Section 8.4.1 as foaming and mobilization of clay sediment did not impact the IWTP during our test but did impact the Steam Stripper operations. OK

Comment #4: *Where or how did you arrive at four years of pump and treat? Please substantiate.*

This estimate is derived from Figure 6-10 in the Draft Final report. A discussion of this figure is provided in Section 6.4.3. The basis of the figure is an analytical solution developed by Johnson and Pankow (1992) (see Draft Report for reference information).

Four years is an extremely generous estimate. Our experience is that the analytical solution represented by Figure 6-10 becomes problematic the smaller the ganglia become. Modeling is a more effective means of predicting the performance of a pump and treat, but this was not within our scope of work.

For the purpose of discussion in Section 9.2, Figure 6-10 was consulted to estimate a reasonable time a conventional pump and treat could remove the five gallons of DNAPL that might remain within the test area. A typical pumping induced velocity of 1.2 m/day was assumed with a pool length of 2 meters. This resulted in a prediction of a 40 year period for a pump and treat to remove the DNAPL. This seemed overly conservative.

Recognizing that either the remaining DNAPL did not exist as a pool or at some point the pool would degrade to individual ganglia (distinct packets of trapped DNAPL), Figure 6-10 was examined again. This time it was assumed the ganglia were an average of .32 meters in length with the same groundwater velocity as before. This resulted in a prediction of a 3 year period for a pump and treat removal of the DNAPL ganglia, more than an order of magnitude different than for a pool.

Finally, it Figure 6-10 was examined assuming very small ganglia (average length of .07 meter) and a pump and treat period of 4 months was derived. This is highly unlikely based upon our experience with residual DNAPL. For ganglia of this size, other physical factors make the predicted curves less reliable.

To be most conservative, four years was estimated for the purposes of discussion in Section 9.2. This is exactly one order of magnitude less than the 40 years predicted for a 2 meter long pool.

The text of Section 9.2 will be amended to instruct the reader more fully on this topic. The text in 9-2 will be amended to read, "Although not modeled, pump and treat remediation alone would take a significant amount of time to remove the remaining DNAPL. Assuming the five gallons is present as residual DNAPL, an inspection of Figure 6-10 suggests that pump and treat would at best remove the DNAPL within 3 years and in as many as 40 years, depending on the condition and distribution of the contamination. Water flooding results in a more effective removal of DNAPL. We did model the effectiveness of a water flood and found that the remaining mass of DNAPL would be removed to below drinking water standards in about 30 to 70 days."

Comment #5: *In my opinion, this paragraph is very subjective. Also, reference your response to the original comment #28 and my first comment on this page.*

Section 6.4.3 provides additional support for this paragraph. Given the limitations of current pump and treat systems to remove residual DNAPL in reasonable amounts of time, given the demonstrated capabilities of SEAR, and given the modeled relative ease with which the final five gallons could have been removed with flooding alone (Section 6.4.3), we believe this paragraph is substantiated and should stand.

Comment #6: *The $3,000 per gallon does not agree with the $1,800 per gallon on page xix of the Draft Final. Please explain.*

INTERA's internal review discovered that our assumptions in calculating an $1,800 per gallon cost for this demonstration were not as representative as we would have liked. We revisited this number and this resulted in an estimate of $3,000 per gallon. This is expressed as an estimate since the "cost per gallon" really does depend on your assumptions. It was decided to revert to a simple "cost of contract" divided by "gallons of DNAPL removed by SEAR" to determine the cost per gallon. We did not include sunk costs, such as the cost of the existing treatment plant and its operation. The contract amount is $1,072,732 and the amount of DNAPL removed by the two SEARs was 341 gallons. $3145/gallon is the result....we rounded to $3000 as, again, this is an illustrative number. If we included the gallons recovered during our site characterization, an integral part of the SEAR process, the cost per gallon would have been $1,275.

Our initial calculation excluded the costs of the further site characterization, the delay costs due to multiple mobilizations and the discovery of the free-phased product, and the atypical testing costs that are more indicative of the demonstration nature of the project than would be incurred for a simple remediation. We decided that this was too complex for the simple purpose of suggesting the economy of this technology, as other costs could just as easily be added into the equation, such as the effluent treatment costs.

Additional Review Comments (Source Unknown)

First General Comment: *The contractor did not provide responses to Comments 36, 38, and 39.*

These responses have been forwarded under separate cover.

Second General Comment: *The contractor makes a number of assumptions about the treatability of the surfactant in the recovered groundwater without presenting specific data. The contractor should obtain specific data from the surfactant manufacturer concerning the material's treatability (e.g., biochemical oxygen demand (BOD), chemical oxygen demand, biodegradability, adsorbability on activated carbon).*

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We agree that a detailed examination of the treatability of the surfactant enriched effluent is important and necessary for a full-scale remediation design. For the purposes of this technology demonstration, however, this was not within the scope-of-work nor the approved Work Plan. We have added some additional discussion of BOD/COD issues vis-à-vis treatment that we hope is responsive to this general comment. Please see Section 8.4.1.2.

Specific Comment #1: *The revised chemical structure is still missing hydrogen atoms bonded to the carbon atoms second from the end of each chain. Correct the figure.*

The figure has been corrected.

Specific Comment #2: *Change "were" to "would".*

This change has been made to the text.

Specific Comment #3: *Verify the effect of the steam-stripped effluent on the base industrial wastewater treatment plant's (IWTP's) effluent by correlating changes in the IWTP effluent with the demonstrations operations.*

This is not within the Scope of Work nor within the approved Work Plan. Instead, INTERA provided process information to the IWTP so they could evaluate the impact the effluent would have on their operations. They agreed that the IWTP could receive the effluent and not cause the plant to exceed their discharge regulatory limits. INTERA did not request, receive, nor evaluate copies of any IWTP effluent characterization tests under this Work Plan. However, we have added some additional discussion of BOD/COD issues vis-à-vis IWTP impact and treatment that we hope is responsive to this comment. Please see Section 8.4.1.2. OK

Specific Comment #4: *Based on the surfactant's theoretical oxygen demand, the BOD:organic ratio is probably greater than 1.5, not 1.0 as stated in the text. Revise the estimated BOD:organic ratio, or justify the assumed value.*

This ratio can be accurately developed after some rudimentary testing. Our experts believe that 1.0 is as accurate an estimate as is possible without this testing. The purpose of the text was only to provide a rough estimate of values. To be responsive to the comment, we will amend the text to reflect a BOD:organic ratio of 1.5, since this value is certainly as valid as 1.0 without testing. The daily-maximum BOD discharge limits for the IWTP that is represented by the surfactant will be changed to 48%. The increase in BOD load for the IWTP will be changed to 6,000 lb/day. OK

I hope that this information assists you in your review of our response. We look forward to your final approval of text. As we've discussed, we will need at least a full week to make final changes and to produce the requested number of reports.

If I send DE&S an accept to all their responses by 15 Dec. final reports by [illegible]

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Duke Engineering & Services

Should you have any questions concerning these topics, please do not hesitate to call. Thank you for this opportunity to be of service.

Sincerely,

Paul B. Cravens, P.E.
Manager
Regulatory Compliance and Environmental Services

TEXT RELATED TO COR's COMMENT #1

Section 6.4.3

Based on the final PITT, approximately 5 ± 4 gallons of DNAPL were left in the pore space between the injectors and extractors at the conclusion of the SEAR demonstration. This corresponds to the removal of between 97.4% and 99.4% of the DNAPL in the demonstration area with an average recovery of 98.5%. The uncertainty in the estimate of the final DNAPL volume is due to the uncertainty in the partitioning tracer measurements (discussed in Chapter 6). However, the question frequently posed is, "how long should remediation operations continue to fully restore the groundwater to drinking water quality."

In order to address this question, a series of analyses were carried out in which the water flood dissolution of the final 5 gallons of DNAPL and the effect on contaminant concentration in groundwater was modeled. Since an excellent match between the UTCHEM predicted partitioning tracer responses and the measured partitioning tracer responses were observed during the initial and subsequent PITTs, the first approach taken was to use the UTCHEM model with the same input parameters to simulate the recovery of the final 5 gallons of DNAPL. As a means of checking the results given by the UTCHEM simulations, a second approach was taken using the analytical solution suggested by Johnson and Pankow (1992).

Well SB-1 was in the deepest part of the channel where the majority of the contamination was initially present, hence the studies focused on the decline in TCE concentration for that well. For the UTCHEM simulations, the injection/extraction began with the DNAPL distribution in the demonstration area as determined by the analysis of the post surfactant flood PITT results. The numerically simulated TCE concentration history is shown in Figure 6-11. From this figure it can be seen that the TCE concentration falls below 5 ppb, the drinking water standard, after 55 days of injection/extraction. At the end of 400 days of simulation, less than 0.2 gallons of DNAPL remains in the aquifer causing a persistent TCE concentration tail on the order 2 ppb. However this concentration is below the drinking water standard and is considered an acceptable level of remediation. Removal of all but 0.2 gallons corresponds to a DNAPL recovery of 99.9%. The remaining DNAPL will probably be removed by natural attenuation due to biodegradation.

These impressive results are due to the removal of the main DNAPL source by the surfactant floods and the dissolution of the final trace amounts by water flooding. In order to further confirm these results, the analytical solution suggested by Johnson and Pankow (1992a,b) was used to model DNAPL dissolution and recovery. The results of the analysis are shown in Figure 6-10. The worst possible scenario is the case in which the 5 gallons is present as a pool of DNAPL since a pool has the lowest surface area for dissolution. In such a scenario it would take about 10 years at a typical water flood groundwater velocity of 5 m/day to recover all the DNAPL as shown in Figure 6-10. If pump and treat remediation with a typical groundwater velocity of 1.2 m/day were used, it would take about 50 years (see Figure 6-10). Since the site was subjected to extensive pumping operations and two surfactant floods (Phase I and Phase II), it is unlikely that the remaining volume of DNAPL is present in the form of a pool. In addition, the region around SB-6 was the lowest point in the aquifer and DNAPL would have accumulated at this point. In all the samples collected from well SB-6 at the end of the surfactant flood, no free phase DNAPL was observed. In addition, no separation of the partitioning and conservative tracers was observed during the post surfactant flood PITT. From these observations it can be concluded that DNAPL did not exist in the form of a pool in the subsurface at the end of the surfactant flood. However, it is highly likely that the remaining DNAPL is trapped in the form of ganglia.

Ganglia lengths in the subsurface are highly variable. If all the DNAPL existed in the form of trapped ganglia and if the average ganglion length was on the order of 7 cm then the Johnson and Pankow analysis estimates that it would take about 30 additional days to recover the 5 gallons. If the average ganglion length was on the order of 12 cm, it would take approximately 70 additional days to recover the 5 gallons at a typical water flood ground water velocity of 5 m/day. Clearly the remediation of trapped DNAPL is a function of the area of DNAPL exposed to flowing water. However the exact nature of the DNAPL ganglia distribution and the DNAPL ganglia size are unknown. Hence these numbers are subject to uncertainty.

The objective of DNAPL remediation is not 100% removal but attainment of drinking water standards. Based on the two approaches discussed in this chapter, it has been shown that it would take between 30 and 70 days to completely remediate the aquifer in the event the DNAPL is trapped in the form of ganglia. Since no free phase DNAPL was observed in the effluent from SB-6 and no measurable separation of the partitioning tracers and conservative tracers was observed during the post surfactant PITT, the assumption that DNAPL is trapped in the form of ganglia is substantiated. Based on the UTCHEM modeling, which incorporates much of the aquifer heterogeneity, it has been shown that it should take only 55 additional days to polish the aquifer to EPA mandated drinking water quality using water flooding after the surfactant flood.

In conclusion it can be reiterated that the additional time required to remediate the aquifer to drinking water standards is on the order of 55 additional days of water flooding. An independent numerical solution of DNAPL dissolution (Johnson and Pankow ,1992a,b), suggest that it could take as much as 70 days to recover the final 5 gallons of DNAPL. Both these techniques again confirm that a small remaining volume of DNAPL can be easily removed by water flooding in a relatively short time after surfactant remediation.

TEXT RELATED TO COR's COMMENT #2 0/2

Additional Text for Section 8.4.1.2

Title changed to "Addressing Surfactant and Cosolvent in the Effluent".

New Paragraphs: "A full-scale application of the SEAR technology will likely substantially impact any local effluent treatment systems, such as a base IWTP or local municipal WWTP. Although a detailed study of the options for addressing this impact is beyond the scope of this report, a general discussion is appropriate.

The modeling of a full-scale SEAR will provide an estimate of the chemical composition of the effluent from the recovery wells. With a knowledge of the constituents, and some rudimentary laboratory tests, the attendant BOD/COD of the effluent can be calculated. The predicted contaminant and BOD/COD loadings can then be compared to the capacities of any downstream treatment systems, such as an on-site steam stripper or an off-site IWTP, or a treatment train comprised of both of these systems. If the capacities of these systems are exceeded by the effluent, then pre-treatment options will have to be considered.

A number of options may be considered at various stages of the treatment train. These include but are not limited to:

1. recycling of surfactant and/or co-solvents on-site (an example of this would be micro-filtration);

2. discharging the effluent to holding tanks, for the purpose of retaining the effluent for timed release during low load periods for the IWTP;

3. discharging the effluent to equalization tanks, to allow mixing with other less concentrated effluent, either from other sources or from the SEAR site;

4. bio-treatment of the effluent prior to release to the IWTP; and

5. higher discharge limits for on-site treatment systems through permitting of these systems.

It is important to note that one or more of these techniques may not be technically or economically feasible given the effluent content. For example, bio-treatment may take too long, thus requiring exceptionally large holding capacities.

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November 10, 1997

Delivered by Facsimile

Mr. Sam Taffinder
AFCEE HQ
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Re: AFCEE SEAR Demonstration
Hill AFB, Utah
Contract No. F41624-95-C-8010

Dear Mr. Taffinder:

Thank you for your letter of November 3, 1997 in which you forwarded comments to our correspondence of October 17, 1997. This correspondence provided you with additional information on the Draft Final Report for the above referenced project. I understand from your letter that you require a response concerning original comments 36, 38, and 39 by today.

Based upon our phone conversation of November 6, 1997, I understand that you did not receive my letter of October 30, 1997. I have since retransmitted it. In this letter I addressed three of four issues still unresolved at the time the Draft Final Report was generated. For the sake of completeness, I will repeat the content of that letter in this correspondence. In this way I can be sure I am being completely responsive to your comments.

In our response to AFCEE and Hill AFB comments to our Draft Final Report, we deferred a few issues pending further examination. This letter is meant to provide closure on all but one of these outstanding responses. Please consider this letter to be an addendum to that response. For ease of review, please refer to our Response to Comments forwarded October 17, 1997.

Item 36: We have reviewed the request for more information listed in Item 36. We characterize this as a "what if" question and consider this to be Out of Scope. We would be happy to address this and any other Out of Scope alternative treatment scenarios if so directed by AFCEE. This request for additional information therefore cannot be addressed at this time.

Delete or defend

Item 38: This is a conceptual diagram and it is not necessary to have the level of detail suggested by this comment. Furthermore, the designers of this conceptual diagram do not agree that an air heater would be required and suggest that a detailed design analysis would be required to determine this. A change to this diagram has therefore not been made.

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November 11, 1997
Page 2

Items 39 and 40: This Response/Action box was incorrectly marked. This comment was fully addressed in our revised discussion under Section 8.4.3.

I hope that this information assists you in your review of our response. I understand we have until November 18, 1997 to address the remaining comments. We will endeavor to meet this deadline. As we've discussed, we will need at least a full week to make final changes and to produce the requested number of reports.

Should you have any questions concerning these topics, please do not hesitate to call. Thank you for this opportunity to be of service.

Sincerely,

Paul B. Cravens, P.E.
Manager
Regulatory Compliance and Environmental Services

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October 30, 1997

Delivered by Facsimile

Mr. Sam Taffinder
AFCEE HQ
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Re: AFCEE SEAR Demonstration
Hill AFB, Utah
Contract No. F41624-95-C-8010

Dear Mr. Taffinder:

In our response to AFCEE and Hill AFB comments to our Draft Final Report, we deferred a few issues pending further examination. This letter is meant to provide closure on all but one of these outstanding responses. Please consider this letter to be an addendum to that response. For ease of review, please refer to our Response to Comments forwarded October 17, 1997.

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Items 39 and 40: This Response/Action box was incorrectly marked. This comment was addressed in our revised discussion under Section 8.4.3.

We reported under our response to Item 28 that we were modeling the dissolution of the DNAPL remaining at the end of the test with the UTCHEM simulator. This work has been completed and we are currently rewriting Section 6.4.3 to address the results. As indicated in our October 17th response, the results show that the remaining 5 gallons of DNAPL could be remediated to below drinking water standards for TCE using a water flood. This could be achieved within 55 days using the same injection and extraction rates used during the SEAR.

FAX

Duke Engineering & Services

To:	Sam Taffinder
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From:	Paul B. Cravens, P.E.
Fax number:	+1 (512) 425-2018
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Date & Time:	11/6/97 2:05:35 PM
Pages:	3
Re:	Here it is again.

DE&S
Duke Engineering & Services

I hope that this information assists you in your review of our response. As we've discussed, we will need at least a full week to make final changes and to produce the requested number of reports.

Should you have any questions concerning these topics, please do not hesitate to call. Thank you for this opportunity to be of service.

Sincerely,

Paul B. Cravens

Paul B. Cravens, P.E.
Manager
Regulatory Compliance and Environmental Services

BOOZ·ALLEN & HAMILTON INC.

300 CONVENT STREET • SUITE 1250 • SAN ANTONIO, TX 78205 • TELEPHONE: (210) 244-4200 • FAX: (210) 244-4206

October 31, 1997
B-09006-0326-4011-0001001

Mr. Sam Taffinder
Technology Transfer Division
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Subject: AFCEE Contract No. F41624-94-C-8013, TDA # ERD ERT 97-01-001, Adequacy of the Contractor's Responses to Review Comments on the Draft Demonstration of Surfactant-Enhanced Aquifer Remediation of Chlorinated Solvent Dense, Nonaqueous Phase Liquid at Operable Unit 2, Hill AFB, Utah

Deliverable #: DT970101.49

Dear Mr. Taffinder:

Booz·Allen & Hamilton Inc. reviewed the contractor's responses to review comments on the subject Intera, Inc., document for completeness and technical adequacy. In general, the responses are complete and well written. However, the contractor should address the attached comments before the final document is issued.

If you have any questions regarding these comments or would like to discuss this document further, please contact me at (210) 244-4218.

Sincerely,

Marc D. Gill

BOOZ·ALLEN & HAMILTON INC.

Marc D. Gill, Ph.D., P.E.
Associate

Attachment

cc: AFCEE/ERC (Lt. Col. Gregory E. Seely)
AFCEE/ERC (Mr. Stephen A. Gagliano) w/o attachment
AFCEE/ERT (Maj. Edward Marchand)
HSC/PKV (Ms. Mary Habib) w/o attachment
BA&H File

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE TEXAS

03 Nov 97

TO: Duke Engineering & Services, Inc
Attn: Mr. Paul Cravens
9111 Research Boulevard
Austin, TX 78758

FROM: HQ AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

SUBJECT: Air Force Comments To Duke Engineering & Services, Inc Responses, First Draft Technical Report, Dated 23 Sep 97, Contract Number F41624-95-C-8010

1. The Air Force has completed the review of subject responses and our consolidated specific comments are at Attachment 1. Overall, your responses are complete and well written. Our specific comments describe clarifications needed in the revised document or issues surfaced in our original comments that you did not fully resolve. In particular, you did not correctly address our original comments 36, 38, and 39. I request that you send me your written responses to these comments by close-of-business 10 Nov. For all the other Air Force comments, I request your written responses by 18 Nov.

2. The purpose of this letter is to remind you that **all** correspondence from Duke Engineering to the Air Force and vise versa **must** have the number of your contract in the subject line. Additionally, I am still awaiting Dr. Richard Jackson's response regarding our opportunity to submit a scientific article for the Bioremediation Journal. The deadlines for the next issues are 17 Nov 97, 31 Mar 98, and 30 Jun 98. If you intend to submit for the Dec 97 issue, I need to know by 06 Nov.

3. If you have any questions or need to contact me, I will be in my office all this week.

Sincerely,

Sam A. Taffinder

SAM A. TAFFINDER, GS-13
Contracting Officer's Representative

1 Attachment (Air Force Comments)

The following are the Contracting Officer's Representative (COR's) comments to Intera'a responses to HQ AFCEE/ERT comments dated 17 Oct 97:

Comment #	Page/Response #/Para or Line	Comment
1	9/Response #28/3	When will the final results be available so Intera can finish Section 6.4.3 and transmit for AF review?
2	10/Response #36/1	My comments to this response also ties into your new paragraph 7.4.3, "Predicted Impacts on the IWTP". Simply stated, Hill AFB is far more concerned about the BOD and COD demands of the steam stripper effluent after surfactant injection than the TCE concentrations. Although Intera was not directly tasked to measure BOD, COD, TSS, etc of the effluent, these measurements were taken during our field demonstration. Therefore, the Final Report should have some general discussion regarding how their concerns over BOD, COD, etc should be addressed. For example, Hill AFB is considering additional holding and equalization tanks, pulsed releases of the effluent, the permitting of the Steam Stripper, and the monitoring of compounds of. interest.
3	23/all of Section 7.4.3	This section seems to be irrelevant without a comparison of predicted impacts to actual impacts. You already have a fairly good discussion of Treatment Challenges in Section 8.4.1 of the Draft Final. If you enlarged this section to include a general discussion of BOD and COD concerns, I think this would be sufficient as long as this discussion included paragraphs 8.4.1.3 and 8.4.1.4. The BOD to organic ratio is most likely 1:1.5.
4	28/Section 9.2, 5th	Where or how did you arrive at four years of pump and treat? Please substantiate.
5	70/Exec Summary/3rd	In my opinion, this paragraph is very subjective. Also reference your response to our original comment #28 and my first comment on this page.

Comment #	Page/Section/Para or	
	Line	
6	70/Exec Summary/	The $3,000 per gallon does not agree with the $1,800
	Page xix/last	per gallon on page xix of the Draft Final. Please explain.
Hill AFB	16/4.1.3.3/next to	Your sentence "This suppresses the effect of heterogeneity
Comment	last sentence	in the material upon the flow field" needs to be clarified.
(Dr. Ginn)		Please explain the meaning of this sentence.

ADEQUACY OF THE CONTRACTOR'S RESPONSES TO REVIEW COMMENTS ON THE DRAFT DEMONSTRATION OF SURFACTANT-ENHANCED AQUIFER REMEDIATION OF CHLORINATED SOLVENT DENSE, NONAQUEOUS PHASE LIQUID AT OPERABLE UNIT 2 HILL AIR FORCE BASE, UTAH

In general, the contractor's responses are complete and well written. However, the following comments describe technical issues in the revised document, along with issues that were not resolved fully. The contractor should address these issues prior to submitting the final document.

General Comments

The contractor did not provide responses to Comments 36, 38, and 39. These comments are related to the treatment of recovered groundwater or the steam stripper effluent. In each case, the contractor stated they were working with Radian Corporation to prepare a response. To minimize delays in delivering the final document, the contractor should submit responses to these comments in a timely fashion.

The contractor makes a number of assumptions about the treatability of the surfactant in the recovered groundwater without presenting specific data. The contractor should obtain specific data from the surfactant manufacturer concerning the material's treatability (e.g., biochemical oxygen demand [BOD], chemical oxygen demand, biodegradability, adsorbability on activated carbon).

Specific Comments

The page and section references cited below refer to the revised text submitted for review.

Item	Page	Section/ Paragraph	Line	Comment
1	NA	Figure 4-1	NA	The revised chemical structure is still missing hydrogen atoms bonded to the carbon atoms second from the end of each chain. Correct the figure.
2	7-22	7.4.3/2	2	Change "were" to "would."
3	7-23	3	NA	Verify the effect of the steam-stripped effluent on the base industrial wastewater treatment plant's (IWTP's) effluent by correlating changes in the IWTP effluent with the demonstration's operations.
4	7-24	1	3	Based on the surfactant's theoretical oxygen demand, the BOD:organic ratio is probably greater than 1.5, not 1.0 as stated in the text. Revise the estimated BOD:organic ratio, or justify the assumed value.

Item	Page	Section/ Paragraph	Line	Comment
5	7-24	1	10	The text states that the IWTP effluent BOD_5 increased by as much as "4,00 lb/d." Verify the correct value of the estimated BOD_5 increase, and correct the text.
6	8-12	8.4.3/2	9	Replace "o" with "on."

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
Technology Transfer Division (AFCEE/ERT)

Sam A. Taffinder
Environmental Scientist
3207 North Road, Brooks AFB, Texas 78235-5357
Office Phone: (210)536-4366 DSN 240-4366
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To: Mr. Paul Cravens	**Phone: (512) 425-2000**	**Pages:**
Fax: (512) 425-2099	**Time: 1630 hours**	**04**
Date: Mon, Oct 27, 1997		**(incl. cover):**

Message

Dear Paul,

This memo is a follow-up to our telephone conservation today regarding the invitation to submit a manuscript for the Bioremediation Journal , namely the Surfactant Injection results, findings, and conclusions from the OU2 Site, Hill AFB, UT. I have attached the cover letter and two pages of the Author Agreement.

I tried to contact Ms. Andrea Lesson concerning the manuscript due date, but I was not able to reach her. I will try again tomorrow. If you have any questions, I will be at Brooks all of this week. Thanks.

Bioremediation Journal
Editorial Office
Battelle
505 King Avenue
Columbus, Ohio 43201-2693 USA
Telephone: 614-424-7604, -5942
Fax: 614-424-3667
Internet: journal@battelle.org

Date: October 20, 1997

To: Sam Taffinder
US Air Force
AFCEE/ERT
3207 North Road, Bldg 532
Brooks AFB TX 78235-5363 USA

From: Andrea Leeson, Managing Editor

Subject: Invitation to Submit a Manuscript for *Bioremediation Journal*

We would like to invite you to submit a manuscript to the *Bioremediation Journal*. We are writing to you because you are listed as an author of an abstract that indicates your involvement in research that could be appropriate for the Journal. The abstract was one submitted this summer to be considered for the program of The First International Conference on Remediation of Chlorinated and Recalcitrant Compounds (May 1998, Monterey, California).

As you may be aware, *Bioremediation Journal* is a quarterly that began publication this year. It was established to provide a peer-reviewed journal focused on bioremediation technologies. The circulation currently is over 2,000 copies. An information sheet describing the aims and scope of the Journal is enclosed. Also enclosed are an author's instruction sheet and related forms.

Please contact us if you have any questions. Our address and other contact information appears in the letterhead. Thank you for considering our invitation. We hope that you will decide to submit a manuscript.

MS #________

(To be assigned by Editorial Office)

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\UTHOR AGREEMENT

This form must be signed on the reverse by all authors and must be submitted before any manuscript can be accepted for publication. It should be submitted with the first draft.

Title: ____

____

Author(s): ____

____

As the Author(s) of this Work, I/we affirm the following in consideration of publication of the Work in *Bioremediation Journal,* owned by Battelle Memorial Institute:

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odifications. *Bioremediation Journal* editorial staff shall make, at their cost, such editorial changes as they deem necesary in my/our final submittal. I/We understand that the Lead Author will have an opportunity to review all such changes within a specified time, in the form of a proof copy, but that final approval of the proof resides with the Editorial Office.

MS #____________

(To be assigned by Editorial Office)

Offprints/Reprints. If this article is accepted for publication, the Lead Author will have the option of ordering offprints (the first 50 copies at no cost) in accordance with information that will be received from the Publisher with the proof copy.

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Lead Author's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

Coauthor's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

Coauthor's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

Coauthor's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

Coauthor's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

Coauthor's Signature — *Date* — Work for Hire? ☐Yes ☐ No

If Work for Hire, Signature and Title of Employer's Representative — *Date*

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
Technology Transfer Division (AFCEE/ERT)

Sam A. Taffinder
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To: Mr. Jon Ginn	**Phone: (801) 777-6916**	**Pages:**
Fax: (801) 777-4306	**Time: 1630 hours**	**Multiple**
Date: Wed, Oct 22, 1997		**(incl. cover):**

Message

Dear Jon,

This memo is a follow-up to our telephone conservation today regarding my sending Intera's responses to Air Force comments to include ALC/EM comments. Their responses to include section re-writes are enclosed for your review. Because Intera's contract expires in about one month and they are yet to deliver the Final Report, I request that you send me your response by 02 Nov.

I will be looking forward to learning more about your follow-on effort at OU2 and perhaps I can be there during the next field work. If you have any questions, I will be at Brooks most of the next two weeks. Thanks.

DE&S
Duke Engineering & Services

9111 Research Boulevard
Austin, TX 78758

512 425-2000
Fax 512 425-2099

October 17, 1997

Mr. Sam Taffinder
AFCEE HQ
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Re: AFCEE SEAR Demonstration
Hill AFB, Utah
Contract No. F41624-95-C-8010

Dear Mr. Taffinder:

Please find enclosed our response to comments on the Draft Final Report for the above referenced project. Please note that there are a small number of responses that are not complete. For example, we are still completing our modeling of the fate of the last five gallons of DNAPL in the test area. We discuss the tentative results of this modeling in the enclosed document, but the backup for this work is not complete and will be forwarded under separate cover next week.

We are following the format in which the comments were provided for ease of review. Each comment is addressed in summary form, and where the change to the report is significant the revised pages are also attached for your review.

I hope and trust that this document is substantially responsive to the AFCEE and Hill AFB comments to the Draft Final Report. Assuming this is so and that any comments to our changes are minor, we believe that if we received your review of this document by October 27, 1997 that we can meet the due date for the Final Report of October 31, 1997. As you know, the production effort for a document of this size and complexity is substantial.

DE&S
Duke Engineering & Services

I want to thank you again for your continued support and guidance in the completion of this important project. Please do not hesitate to contact me or Dick Jackson should you have any questions concerning this document.

Sincerely,

Paul B. Cravens

Paul B. Cravens, P.E.
Manager
Regulatory Compliance and Environmental Services

Attachment: Response to AFCEE and Hill AFB Comments

cc: Dick Jackson, INTERA
Tom McLean, AFCEE (without attachment)

Responses to Review Comments on the Draft Final

Demonstration of Surfactant-Enhanced Aquifer Remediation of Chlorinated Solvent DNAPL at Operable Unit 2
Hill Air Force Base, Utah

The following document lists a response to each of the review comments received by INTERA on the AFCEE SEAR demonstration's Draft Final Report. The comments and the corresponding responses are formatted in a manner similar to the way they were received for ease of review. Where appropriate, the requested revisions or additions to the document are attached for review. These attachments follow the order of the comments listed below. The page numbers in the revised document have changed, and will be finalized once all of the revisions are accepted.

1.0 AFCEE Comments

1.1 General Comments

1. Theoretical discussions that contain equations should include a definition of each variable and the appropriate units for that variable.

   Response/Action: INTERA has revised the sections containing equations and added definitions and units for variables where necessary and appropriate.

2. The section on effluent treatment engineering (Section 7.0) should include a discussion of the biochemical and chemical oxygen demands of the stripped effluent from the source recovery system (SRS) when treating groundwater containing surfactant and isopropyl alcohol cosolvent. The discussion should focus on the effect that the effluent has on the base's industrial waste water treatment plant (IWTP) and the IWTP's ability to meet its permitted discharge limits.

   Response/Action: The Work Plan did not anticipate tracking the IWTP influent and effluent during the SEAR demonstration, and so this data was not collected. Prior to the demonstration, the IWTP was consulted and given estimates of contaminant loadings, which they approved. These predictions, and a discussion of the anticipated impact on the IWTP by RADIAN have been added to the report as a new section: 7.4.3 Predicted Impacts on the IWTP. The new text is attached for your review.

3. The section on cost (Section 8.0) does not appear to include the cost of fully treating the liquid effluent from this technology. This section should include all of the costs for a full scale application.

   Response/Action: The Work Plan did not anticipate tracking the cost of IWTP treatment of the SRS waste stream, and so we will not be able to address specific IWTP cost issues for the SEAR demonstration in the final report. However, we have provided an estimate of IWTP treatment costs for the full scale cost estimate in Section 8.0. The new text has been inserted as the second paragraph of Section 8.4.3, and is attached for your review:

4. The conclusions and recommendations (Section 9) overstate the errors of past remediation efforts and the necessity of implementing this technology at all sites contaminated with chlorinated solvents. The text should be rewritten in a style appropriate for a technology demonstration report.

   Response/Action: Section 9.0 has been rewritten. The entire new section is attached for your review:

5. The list of acronyms and abbreviations should follow the list of appendices in the front matter.

   Response/Action: INTERA has placed the list of acronyms behind the list of appendices.

6. The analytical data in Appendix B were reviewed to assess data quality and usability. In general, the data quality and usability are acceptable. The AFCEE quality assurance/quality control (QA/QC) guidance documents (i.e., Handbook for the Installation Restoration Program [IRP] Remedial Investigations and Feasibility Studies [RI/FS] and the QA Project Plan) were not followed. However, the QA/QC performed was consistent with the method SW8260 QA/QC requirements. All QA/QC results were acceptable, except for high matrix/matrix spike duplicate (MS/MSD) percent recoveries for trichloroethene (TCE). The contractor should state whether the high MS/MSD percent recoveries indicate a bias toward high TCE concentrations results or whether they are an artifact of the high sample concentrations.

   Response/Action: Prior to the preparation of the QAPP for this project, we discussed with AFCEE the fact that the AFCEE guidance documents for this submittal were designed for RI/FS projects and therefore not entirely appropriate for this work. As a result of the feedback we received from AFCEE, we prepared and submitted a plan more appropriate for the work at hand for review by AFCEE. This document was commented upon, amended, and approved for use by AFCEE prior to use on the project. This document was amended for Phase II of the work and again reviewed and approved for use by AFCEE. Since no action was required, INTERA has no further response to the first part of the comment.

In reference to the high MS/MSD recoveries for TCE, the explanation provided by Data Chem, the laboratory performing the analysis was:

"The large dilution factor coupled with a high amount of the analyte detected in the sample caused the recovery for TCE to fail QC recovery limits."

In other words, because the sample already had a high concentration of TCE, spiking it with additional TCE caused recoveries that exceeded control limits. This problem did not occur with any of the surrogate spike analytes or in any matrix spikes in samples containing only small amounts of TCE.

To perform MS/MSDs correctly, the sample must be divided into three representative replicates. Two of them are then spiked, making the MS and MSD. This can be done accurately for soil samples if the original sample is preserved/extracted in methanol and MS/MSDs are performed on aliquots of this extract. However, for these soil samples, the current EPA guidelines were followed, i.e., the soil samples were not preserved/extracted with methanol in the field. As a result, the lab tried to split the soil sample into three representative replicates before adding the methanol for extraction. Herein lies the problem. It is highly unlikely that each of the replicates contained the same amount of original TCE contamination.

Spiking each of these highly TCE-contaminated replicates with small but equal amounts of TCE gave poor spike recoveries because the spikes could not be distinguished from the original concentrations in the replicates. Therefore, if the original TCE concentrations in the replicates were not equal, the spike recoveries would appear to be out of compliance. The poor spike recoveries are an artifact of the high TCE concentrations in the samples and the procedure used for preparing the replicates, and do not effect the data use for the soil sample analysis, which was to screen the contaminated zone for DNAPL saturations.

1.2 Specific Comments

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
1	3-8	Figure 3-2	NA	Correct this figure to show that the stainless steel casing was used for the first ten feet above the well casing.	The figure has been corrected and is attached for review.
2	3-21	Figure 3-7	NA	The labels for the test wells are difficult to read. Provide clear labels for the wells to orient the reader.	The figure has been revised and is attached for review. The well labels have been changed and the shading has been removed to make them more legible. A north arrow and axis labels have been added to orient the reader. The page size has been increased to an 11x17 format.
3	3-28	4	3	The second sentence in this paragraph is duplicated. Correct the text.	The duplicate sentence has been removed.
4	3-29	2	3	Provide a complete reference for Mariner et al., 1997.	The list of references has been updated to include Mariner et al, 1997. The revised Section 10.0 is attached for your review.
5	3-31	Table 3-6	NA	Explain the significance of the numerical averages of the dense non-aqueous phase liquid (DNAPL) saturation values measured at unevenly spaced intervals in the soil strata.	Soil samples to be analyzed for VOCs at the laboratory were chosen on the basis of high PID head space readings, and on the stratigraphy encountered during the drilling of the boreholes. Therefore, the numerical averages of DNAPL saturation values listed on Table 3-6 represent nothing more than a qualitative indicator of the relative amount of contamination encountered in each borehole. Quantitative comparisons are not valid since these means are biased by the fact that the number of samples in each set varies from borehole to borehole. The greatest amount of DNAPL was found in the deepest portion of the channel centerline, while boreholes advanced into the flanks of the channel higher up in the alluvium are much less contaminated. Classical statistical measurements, such the numerical

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
					average, do not take into account the spatial distribution of the samples taken from a population, so the spacing of the samples is irrelevant. Spatial relationships in a sample set can be investigated using geostatistical methods developed for this purpose, but in this case, the data are too sparse to derive any other meaningful conclusions. The text has been revised to clarify the meaning of the averages included on the table. The new paragraph is attached for review.
6	4-5	2	6	The text states that the commercial name of the surfactant is "Aerosol MA-80I", but it is referred to as Aerosol MA80-I in the following paragraphs. Verify the correct name of the surfactant , and correct the text.	The correct name is Aerosol MA 80-I. References to the trade name of the surfactant in the text have been revised.
7	4-6	Table 4-2	NA	The title of this table is "Summary of Phase Behavior Experiments ...." but it lists only the test conditions. Change the title to reflect the contents of the table.	The title of the table has been changed to read "Different Types of Phase Behavior Experiments Performed with Surfactant Solutions and Hill DNAPL".
8	4-7	Figure 4-1	NA	The chemical structure is missing bonds for two of the carbon atoms. Please correct the figure.	The figure has been corrected and is attached for review.
9	4-13	Figure 4-4	NA	Provide a legend describing the significance of each data symbol.	A legend describing each symbol has been added to the figure, which is attached for review.
10	4-15	2	NA	The text states that the duration of the tracer slug injection (t_s) and the termination time of the tracer test (t_f) were obtained by integrating the tracer concentration curves. The integration of the concentration response curves should yield results in units of mass. Clarify how the t_s and t_f values were obtained.	The reference to "the values of t_s and t_f " in the text is a mistake. The text has been corrected to read: "The first moments of the partitioning and nonpartitioning tracers $\bar{t}_p$ and $\bar{t}_n$ are obtained by numerically integrating the corresponding tracer response curves".
11	4-18	Figure 4-5	NA	Provide a legend title.	A legend title has been provided. The figure is attached for your review.

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
12	4-22	Figure 4-6	NA	See Comment 2.	This figure has been revised to make it more legible. The shading has been removed, and a scale, north arrow, and surface features have been added to orient the reader. The labels for the wells have been changed to make them legible, and the page size has been changed to 11x17 format. The new figure is attached for review.
13	4-26	Figure 4-8	NA	Show the test wells or some other surface features to orient the reader.	This figure has been revised to make it more legible. The shading has been removed, and a scale, north arrow, and surface features have been added to orient the reader. The labels for the wells have been changed to make them legible, and the page size has been changed to 11x17 format. The new figure is attached for review.
14	4-32	1	6	Provide a complete reference for Chun Huh, 1979.	The reference to "(Chun Huh, 1979)" in this paragraph should be "(Huh, 1979)". The text has been changed. This reference is included Section 10.0 References (see item #4).
15	4-32	1	9	Provide a complete reference for Brooks and Corey, 1966.	The Brooks and Corey (1966) reference has been added to Section 10.0 References.
16	5-2	3	2	Table 5-1 indicates that the initial water flood took two and a half days, but the text states that it took two days. Correct this discrepancy.	The text has been revised to state that the initial water flood took two and half days.
17	5-3	Table 5-1	1	Correct the value of cumulative time for water injection.	The "0.5" value has been changed to "2.5".
18	5-4	Figure 5-1	NA	The injection and extraction wells are labeled incorrectly, and well SB-1 is shown as both an injection and extraction well. Correct these discrepancies.	The diagram has been corrected to show the wells in their proper locations. The bypass plumbing for the water flood has also been added to the drawing. The revised figure is attached for review.
19	5-4	Figure 5-1	NA	Revise the figure to show the water flood bypass piping from the water tank to the injection wells	See item # 18.

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
20	5-5	Figure 5-2	NA	Well SB-8 is labeled incorrectly as an extraction well, and the well piping is not connected to the injection piping. Correct the figure.	The figure has been corrected and is attached for your review.
21	5-10	Table 5-3	4	Provide a list of methods used to preserve the samples from the wells U2-1, SB-1, and SB-5 during days 9-11.5.	The preservation method for the extraction wells during days 9-11.5 has been added to the table. The word "ice" in the table has been replaced with "4°" since a refrigerator was used to store the samples in the field laboratory on site. In addition, the table has been corrected to show that sulfuric acid was not used as a preservative for VOC samples. Acid preservation was not required because of the high concentrations of contaminants in the samples, and the short (hours) holding time prior to analyzing the samples. The revised table is attached for review.
22	6-5	Table 6-2	1-5	Clarify the analytes and preservation requirements used for wells U2-1, SB-1, and SB-5.	The table has been corrected by removing extraneous and duplicate lines from the "Analyses" and "Analytes" columns. Tables 6-3 and 6-4 have been revised in the same manner. The revised tables are attached.
23	6-9	Table 6-5	NA	Explain why the bromide recovery was not analyzed.	A paragraph explaining why the bromide recovery was not analyzed has been added to Section 5.3.1 on the initial PITT. The explanation was placed into that section because bromide was used in the tracer suite but not analyzed in the initial PITT. An explanatory sentence has also been placed into the text for the intermediate PITT. The revised text is attached for your review.
24	6-12	3	6	The discussion of the effect on the systematic errors on the measured volatile organic compound (VOC) concentrations leaves some doubt about the accuracy of these data and the validity of the conclusions drawn. Expand the discussion of VOC analysis to include an estimate of accuracy and a discussion of data QC.	The sentence "Systematic errors...can also induce errors...." was not accurate and has been removed from the text. There were no systematic errors in the TCE analyses. A discussion of accuracy and data QC has been added to the text, which is attached for review.
25	6-19	Figure 6-6	NA	The figure shows a straight line through five days of data (i.e., days 20-25) extrapolated for another	When DNAPL is removed by solubilization only, its behavior is extremely similar to that of a partitioning

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
				30 days. Justify the assumption that the material removal would continue to follow the same mathematical function over time as the concentrations decrease more than three orders of magnitude, and provide references from the technical literature to support this assumption.	tracer. The solubilized DNAPL behaves exactly like a partitioning tracer. The slow dissolution of DNAPL into flowing water is similar to partitioning of tracers out of a nonaqueos phase into an aqueous phase. Under these circumstances the solution of the advection diffusion equation can be approximated by a exponential decline. The solution of the advection diffusion equation under these conditions is discussed in Maroongroge (1994). A linear decline on a semi-log plot for the tracers was observed by Jin (1995) and a technique for extrapolation of component concentrations was developed. The slope of the decline is a function of the mass transfer rate, which is in part dependent upon the velocity of the groundwater is flowing througn the contaminated zone. The assumption is that this velocity will not change, and that the kinetics of the mass transfer will not change. Maroongroge, V., 1994. "Modeling and Application of Tracers for Reservoir Characterization," Ph.D. Dissertation The University of Texas at Austin.
26	6-20	2	8	The text states that the desired injectant concentration was 1000 mg/L for the 1-heptanol tracer and 750 mg/L for 1-propanol and 1-hexanol. Explain why a higher target concentration was selected for 1-heptanol and why the actual injectant was approximately 60 percent of the target value.	The reference to a injectate concentration of 1000 mg/L for 1-heptanol was a typographical error. The target concentration for 1-heptanol was 700 mg/L. The text has been corrected.
27	6-20	Table 6-7	NA	See Comment 23.	See Item #23. An explanatory sentence has been placed into the text.
28	6-29	1	2	The 5 gallons of residual DNAPL were measured during the tracer test that ended somewhere around day 25. Therefore, the extrapolation over time, if valid, extends approximately 30 days (see Comment 25). This does not agree with the 70 days predicted in Table 6-10. Correct this discrepancy.	The dissolution prediction of 30 days was based on extrapolation of actual concentration data from the field. The prediction of 70 days in Figure 6-10 is an independent prediction based on an analytical solution of dissolution of DNAPL, and is highly dependent on the assumed distribution of the remaining DNAPL in the analytical model. (see Figure 6-10). Given the large degree of uncertainty over the distribution of the

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
					DNAPL, and the fact that in actuality it is quite possible that less than 5 gallons remained at the end of the SEAR demonstration, the two estimates actually agree quite well. We are currently modeling the dissolution of the DNAPL remaining at the end of the test with the UTCHEM simulator. Preliminary results show that for approximately 5 gals of DNAPL remaining, it takes 55 days to remediate the aquifer to drinking water standards via water flood using the same injection and extraction rates used during the SEAR. Once the final results are available, Section 6.4.3 will be rewritten to clarify this issue. The revised section will be forwarded for review as soon as it is completed.
29	7-12	1	2-3	Add HETP and NRTL to the list of acronyms and abbreviations.	These acronyms have been added to the list of acronyms and abbreviations.
30	7-17	4	7	The phase "to the stripper" is duplicated in this sentence. Correct the text.	The duplicated phrase has been removed from the sentence.
31	7-21	Figure 7-9	NA	No data are provided for isopropyl alcohol concentration, and the symbol is not shown in the legend. Provide the data, and correct the legend.	The graph and legend have been corrected to include isopropyl alcohol. The revised figure is attached for review.
32	7-22	2	4	The text states that baseline (no surfactant) conditions were modeled, but no results are presented. Modify the text to include the baseline modeling results.	The quoted statement is misleading. The sentence stating that baseline modeling had been conducted has been deleted.
33	7-23	Figure 7-10	NA	No data are provided for measured TCE effluent (parts per million), and the symbol is not shown in the legend. Provide the data, and correct the legend.	The graph and legend have been corrected to include measured TCE concentration. The revised figure is attached for review.
34	8-3	4	3	The total demonstration project cost exceeded 1,050,000, and approximately 341 gallons of solubilized residual DNAPL were recovered,	The cost per gallon has been corrected to about $3000. A discussion clarifying the cost calculation has been added to Section 8.0, and is attached for your review.

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
				which equates to about 3,079 per gallon. Explain how the estimated cost of 1,800 per gallon of solubilized DNAPL was calculated, and provide supporting information.	
35	8-4	1	7	It is not necessarily true that all Air Force sites with chlorinated solvents in the groundwater have a DNAPL source in the soil. There are several scenarios where water contaminated with soluble chlorinated solvents could have leaked or might have been spilled. Correct the text.	The final sentence of the paragraph has been removed.
36	8-6	2	7	Suggest a method for treating the condesate separately prior to discharge, and estimate the cost of this treatment for comparison to show whether the approach is economically feasible.	INTERA is currently working with Radian to respond to this comment.
37	8-6-	2	5	See Comment 6.	The correct name for the surfactant is Aerosol MA 80-I. References to the trade name of the surfactant have been revised.
38	8-10	Figure 8-2	NA	Activated carbon adsorption of organic vapors from an air stripping tower typically requires that the air be heated to minimize the condensation of water in the carbon bed. Show the air heater in this figure.	INTERA is currently working with Radian to respond to this comment.
39	8-11	8.4.3	NA	Table 8-2 indicates that approximately 5,190 pounds of stream stripper bottoms will require treatment and discharge every hour (a similar volume is generated from air stripping). The stripper bottoms will contain significant concentrations of both the surfactant and cosolvent with resulting high biochemical and chemical oxygen demand concentrations. Include the cost of treating the stripper bottoms to show the complete cost of treating the recovered groundwater and DNAPL.	INTERA is currently working with Radian to respond to this comment.
40	8-14	Table 8-6	NA	See Comment 39	See Item 9.

Item	Page	Section/ Paragraph	Line	Comment	Response/Action
41	9-3	1	13	DNAPL has been removed from alluvium at other Air Force sites without the use of tracer tests. Revise the text to indicate that, while tracer tests are valuable, they are not a requirement for the removal of DNAPL from the alluvium.	The text has been revised to indicate that partitioning tracer tests are necessary if the source zone characterization is to be accurate to within 50% (see Jin et al, 1997). See General Comment Number 4.
42	NA	Appendix A	NA	Provide the well log from well U2-1 for comparison with the new wells.	The geologic and well construction log for U2-1 has been added to Appendix A.
43	NA	Appendix B	NA	Explain how the results from the high pressure mercury injection test were used, and provide references for the test method and interpretation of results.	An explanation of the mercury injection test and references for the test method and interpretation of results have been included in the appendix. The text is attached for review.;
44	NA	Appendix C	NA	Provide the pneumatic slug test results for well SB-1.	The slug test results for well SB-1 have been added to the Appendix.

2.0 Hill Air Force Base Comments

General Comments: (Dr. Jon Ginn, Hill AFB EMR)

1. (a)For ease of comparison, a summary table should be included that lists predicted values such as the temporal moments for the tracers and well pairs and actual observed temporal moments for the tracers and well pairs. Retardation values should also be reported for tracers and well pairs. (b)Also, can an error estimate be calculated for the temporal moments? (c)How are the concentrations on the tailing side of the tracer curves extrapolated, and are the extrapolated concentrations used in the calculation of the recovery efficiency of the tracers? What is the detection limit for the tracers in the effluent and what percentage of the integrated tracer curve is from the extrapolated data?

    *Response/Action: (a)*A summary table has been added to Section 6.4 as Table 6-9 with accompanying text in sub-section 6.4.1. Subsequent chapters have been renumbered to reflect the addition of the new sub-section. The table lists the predicted and actual temporal moments for the initial PITT partitioning tracers for each well pair. The table also lists the retardation factors for each of the tracers. The new table and text will be forwarded with the revised Section 6.4 when the additional UTCHEM modeling is finalized (see response to AFCEE Item #28).

    The accuracy of estimating the residual DNAPL saturation depends on the accuracy of measurement of the partition coefficients, accuracy of measuring the volume of fluid produced, and the accuracy of measuring the tracer concentrations. A combination of all these errors leads to an overall error in determining the first temporal moment of the tracers. Since the method of moments relies on the difference between the first temporal moments of the partitioning and nonpartitioning tracers, some of the errors cancel out.

    In order to estimate the errors in determining the residual DNAPL saturations, the data from eleven laboratory partitioning tracer experiments were carefully analyzed. These partitioning tracer experiments were conducted on soils contaminated with a known volume of DNAPL. Since the DNAPL saturations in the soil columns were known, a comparison of residual NAPL volume as determined by independent mass balances and the partitioning tracers was made. Based on these results, it was determined that the standard deviation between the mass balance estimates of residual NAPL saturation and partitioning tracer estimates was $\pm 7.0\%$. Since our objective was determine the errors in the retardation factors, data from five partitioning tracer experiments with uncontaminated soil were analyzed. The expected retardation of the partitioning tracers was 1.0. The results from these experiments indicated that the average retardation of the partitioning tracers was 1 ± 0.035. From this it was concluded that the error in retardation of the partitioning tracers was ± 0.035. For a more detailed discussion the errors in partitioning tracer measurements, please refer to Dwarakanath (1997).

As described by Pope et al. (1994) and Jin (1995), at low concentrations partitioning tracers display an exponential decline. This behavior in the tails of the tracers can be explained mathematically using the solution of the advection diffusion equation. Based on this observation, a technique for extrapolating the tails of tracer data was developed by Jin (1995) to improve the accuracy of residual DNAPL saturation estimates. The method used to extrapolate the tracer data has been added to Section 4.1.3.2 of the AFCEE SEAR Report. A brief summary is given below.

Since much of the information obtained from a PITT is contained in the tail of the tracer response curves, these response curves should be as complete as possible. Unfortunately the tracer tails are often incomplete either due to the dilution of the tracer concentration below the detection limit of the tracers (in this case the detection limit was between 3 and 5 mg/L) or limitations on the length of the test. However, the data in a tracer response curve can be divided into two parts. The first part represents the data from zero to the time t_b where it becomes exponential, and the second covers the exponential part which goes from t_b to infinity. After time t_b the tracer response follows an exponential decline given by:

$$C = C_b e^{-\left(\frac{t-t_b}{a}\right)}$$

where 1/a is the slope of the straight line when the tracer response curves are plotted on a semi-log scale, and C_b is the tracer concentration at time t_b. The improvements in the estimates of residual DNAPL saturation when extrapolation is used are listed in Jin (1995).

In the tracer analysis at Hill OU2, less than 5% of the tracer data was extrapolated. The extrapolated tracer data was not used to calculate tracer recoveries. The tracer recoveries were based on the measured tracer concentrations and hence reflect the mass of tracer recovered during field operations.

2. For ease of comparison, a summary table should be included that shows all measurements of DNAPL recovery from both Phase I and Phase II. This table would be similar to Table 6-9 but include both phases. Also, show the DNAPL recovered from the pumping prior to the study.

   Response/Action: Table 6-11 has been added to Section 6.4. The table lists the estimates of DNAPL recovered during the AFCEE SEAR demonstration, including the DNAPL pumped out of the well field prior to the flood, and the DNAPL recovered during both Phase I and Phase II. The new table and text will be forwarded with the revised Section 6.4 when the additional UTCHEM modeling is finalized (see response to AFCEE Item #28).

3. The discussion of the error estimate in Section 5.3.2 should be expanded to more clearly identify how the average error value of 0.035 was arrived at and how this was used in subsequent error estimates.

   Response/Action: The response given in 1b has been added to Section 5.3.2.

2.2 Specific Comments: (Dr. Jon Gin, Hill AFB EMR)

Section 2.2.2 Other Remedial Activities: Second paragraph..."Current work at OU2 under the ROD includes the construction of two interceptor trenches in the plume area...". Only one trench is being constructed in the off-base plume area.

Response/Action: The sentence has been corrected to read "includes the construction of an interceptor trench in the off-base plume area".

Section 2.3.2 Site Stratigraphy: Figure 2-4 "Block Diagram of the Channel Eroded into the Alpine Clay needs a scale and axis labels. Figure 2-3 also needs axis labels.

Response/Action: These figures are now numbered 2-4 and 2-5 (see Item 2 in Section 3.1 below). Scales and axis labels, as well as contour labels have been added to these figures. In addition, the shading has been removed from each figure to make them more legible when reproduced. North arrows and site surface features have been added to the maps to orient the reader as well. Finally, the page size has been increased to 11x17 format.

Section 3.1.2 Soil Sampling: End of the third paragraph. Text indicates that 3 sub-samples of the aquitard were collected to measure DNAPL penetration into the clay. What were the results for these samples? Was any DNAPL found in the clay? Were there any lab tests done to determine an adequate surfactant equilibrium contact time with the clay interface?

Response/Action: Of these sub-samples, only two were analyzed for VOC contamination. Sample SB-111, collected approximately 9 inches below the clay contact in SB-1, was chosen for analysis on the basis of PID head space readings. No visible contamination was noted in the clay core, and the DNAPL saturation obtained from the VOC analysis was 0.1%, as reported in Table 3-6. Sample SB-701, obtained from SB-7, was silty clay core from a thin wet silty stringer in the Alpine clay. The head space analysis on this sample did not register any contamination, but the sample did contain some VOC's at low concentrations in the dissolved phase (see the analytical report from DATACHEM in Appendix A). A

NAPLANAL analysis of the laboratory results determined the DNAPL saturation for SB-701 to be zero.

Laboratory tests conducted with surfactant solutions utilized alluvial soils. For the purposes of the SEAR technology, the clay aquiclude at OU2 acts as a no-flow boundary that provides capillary barrier for the DNAPL targeted for remediation. Additional samples of the clay collected during prior to the AATDF surfactant/foam flood conducted adjacent to the SEAR demonstration area showed that the DNAPL had penetrated into no more than the first foot of the clay at the most, and that the saturations attenuated very rapidly. Because the interconnected pore space in the clay is so small, residual saturations of DNAPL in the clay actually represent an insignificant DNAPL mass.

Section 3.4.1 Aquitard Properties: Figures 3-7 and 3-8 need axis labels. Also prefer that these types of figures be presented in 11x17 format.

Response/Action: Scales and axis labels, as well as contour labels have been added to these figures. In addition, the shading has been removed from each figure to make them more legible when reproduced. North arrows and site surface features have been added to the maps to orient the reader as well. Finally, the page size has been increased to 11x17 format.

Section 3.4.3 DNAPL Composition and Distribution: Second paragraph - delete the redundant sentence..."In particular"..."

Response/Action: The redundant sentence has been removed. See Item 3 in Section 1.2.

Section 4.1.3.1 Partitioning tracer Column Studies: 1st paragraph - how was the experimental accuracy of ± 0.035 determined?

Response/Action: See the response to general comment 1(b).

Section 4.1.3.1 Figure 4-4: Symbols for the tracer test data need to be identified.

Response/Action: A legend identifying the tracers has been added to the figure. See item 9 in Section 1.2 above.

Section 4.1.3.2 The Partitioning Tracer Data Analysis Technique: Show units for factors used in equations 4-7.

Response/Action: Units have been provided for all of the equations presented in the text.

Section 4.1.3.3 Surfactant flood Column Studies: *Paragraph four.* It is implied that the addition of polymer could serve as mobility control for the surfactant solution. If the viscosity of the surfactant solution is increased, how does this promote the solution to travel through areas of lower permeability? Wouldn't the solution as a whole follow the path of least resistance and go through the higher permeability zones?

Response/Action: Fluid flow through porous media is governed by two variables, resistance due to the medium and internal resistance of the fluid. The resistance due to the medium is due to the pore throat geometry and is described by the permeability of the medium. The resistance due to the internal friction of the fluid is caused by its viscosity. As an analogy, the system can be thought to behave as two resistances in series. When polymer is added to the injectate, the viscosity of the fluid is significantly increased, and therefore the resistance to flow through the porous media due to internal friction is increased. Under these circumstances, the resistance due to the internal friction (viscosity) is greater than the resistance due to the pore throat geometry (permeability), and thus the effect of viscosity dominates the effect of permeability. This suppresses the effect of heterogeneity in the material upon the flow field. In theory, if the viscosity were increased infinitely, the effect of all of the heterogeneities will be negated, although an exceedingly high gradient would be need to force the fluid to flow through the porous media.

Paragraph five: Although the pre-surfactant and post-surfactant permeability values were similar as reported in Table 4-6, the relative percent difference between the pre and post permeability for the Hill soil is about 18%. Therefore, the statement that the surfactant restored the soil to its original condition is not supported.

Response/Action: The errors in the permeability measurements are usually on the order of 10%. In addition, xanthan gum polymer was used along with the surfactant to flood the cores in the experiments listed in Table 4-6. Since the displacement of polymer by water is a very inefficient process, it takes about 50-60 pore volumes of water to completely displace the polymer from even a small column. In the experiments listed on the table, this many pore volumes were not put through the columns, hence some loss of permeability was observed. This loss of permeability in the column after the surfactant/polymer flood accounts for the observed reduction in permeability on the order of 18%. In the field application of SEAR, polymer was not used, and no reduction of hydraulic conductivity was observed.

This explanation has been added to the text, and the statement that the "surfactant flooding restored the soil in the column to its original condition" has been deleted. The revised section is attached for review.

<u>Section 4.2.1 SWIFT II Scoping Model Implementation</u>: The reported hydraulic conductivity for the site ranges from 2.8 ft/day to 51 ft/day. What was the rational for choosing 57 ft/day?

Response/Action: The range 2.8 ft/day to 51 ft/day reported on Table 4-8 is the range of the distribution of conductivity values used in the model to achieve calibration. The conductivity values from pumping tests reported by Radian (1992) "range from 42.6 ft/day to 116 ft/day for the alluvium in the buried channel" (Section

2.4.2). The value of 57 ft/day was used to initialize the model prior to calibration and is therefore not significant. This sentence has been removed from the text to remove the confusion. In addition, the title of Table 4-8 has been revised to indicate that the values are for the calibrated model.

Section 4.2.2 UTCHEM Implementation: Table 4-6. How was the value of 1345 gal of total DNAPL volume arrived at?

Response/Action: The DNAPL volume initialized in the model (1345 gallons) included both the DNAPL in the well field and, because the model has to be larger than the demonstration area, DNAPL outside of the well field pattern. The DNAPL inside the well field was estimated from the soil core data, and by assuming a residual saturation remaining in the area of the pool that was pumped out of the well field prior to the SEAR flood. The majority of the DNAPL outside of the model's well field was initialized in the northern pool area, and a small amount of immobile DNAPL was inferred to exist to the south, both on the basis of an estimate of the highest DNAPL pool elevation.

Section 6.3.3.2 Results and Analysis: Why was 1-propanol used as the non-partitioning tracer for the calculation of the residuals instead of bromide. Recommend including a summary table indicating the tn and tp values for the various tracers and well pairs. Also, it would be helpful to give an example calculation showing how the final residual DNAPL values were determined.

Response/Action: Bromide is added to a PITT tracer suite as a conservative measure to add a factor of safety into the design (see the response to AFCEE item # 23). Bromide is analyzed with an ion-specific electrode, while the concentration of 1-propanol is analyzed by GC, along with the other alcohol tracers and the VOCs. Therefore, unless a problem is suspected, the results of the GC analyses are used to calculate the residual saturation, volume of DNAPL, and swept volume.

An example of a PITT analyses has been included in the final report as an EXCEL spreadsheet on disk in Appendix D.

Section 6.4.3 Dissolution Time Predictions for the Remaining DNAPL: At the end of paragraph 1, the value of 2 ppb is reported for the total contaminant concentration in the effluent. However, this is in disagreement with the value reported on pp 6-14 (8 ppm).

Response/Action: The value of 8 mg/L reported on page 6-14 is the VOC concentration measured at SB-6 in the middle of the demonstration area at the end of the surfactant flood, as shown on Figure 6-5. The value of 2 ppb referenced on page 6-27 is an estimated VOC concentration in the effluent from the well field had the post-surfactant water flooding continued for about 50 more days. This estimate is based on the trend of the exponential decline of the contaminant concentrations in wells SB-1, SB-5 and U2-1 at the end of the demonstration, and assumes that the kinetics of the mass transfer would not have changed.

We are currently modeling the dissolution of the DNAPL remaining at the end of the test with the UTCHEM simulator. Preliminary results show that for approximately 5 gals of DNAPL remaining, it takes 55 days to remediate the aquifer to drinking water standards via water flood using the same injection and extraction rates used during the SEAR.

Once the final results are available, Section 6.4 will be rewritten to clarify this issue. The revised section will be forwarded for review as soon as it is completed (See AFCEE Item #28).

2.3 General Comments: (Mr. Steve Hicken, Hill AFB EMR)

1. I agree that the use of PITTs appears to be far superior to relying only on soil borings to determine contaminant mass. However, do they have a weakness in the fact that at sites with a high degree of heterogeneity, i.e. lower permeability zones (silts, clays), the residence time for the PITT may be insufficient to contact DNAPL that has penetrated low permeability materials for a long period of site history. If this is a problem, is there a correction factor that can be applied for a specific site based on the percentage of lower permeability zones?

   Action/Revision: DNAPL penetration into low permeability material is possible only if the entry pressure of the material is exceeded. In other words, DNAPL can only enter a pore space if the driving force (DNAPL head) exceeds the capillary pressure in the pore. The smaller the pore throat is, the higher the DNAPL column (head) must be to exceed the entry pressure and flow into the pore. This concept was verified numerous times by the difficulty experienced in introducing TCE into lower permeability soils in multilayered column studies at UT.

   There are some fine sands and silts at the very bottom of the DNAPL pools in the alluvial aquifer at OU2 that contain DNAPL. The amount of contamination entrained in these sediments is minor compared to the mass in the coarser alluvium. During a PITT, given sufficient time, streamlines carrying tracers will flow through these zones. For a site with a higher percentage of DNAPL contaminated low permeability materials, this would become a primary design issue. For Hill OU2, however, the DNAPL mass contained in finer grained sediments within the alluvium is felt to lie within the uncertainty of the PITT results, and is therefore considered negligible. A properly selected surfactant solution will solubilize the majority of this residual saturation. However, a surfactant flood with mobility control such as polymer or foam can make the process much more efficient, and much less surfactant would be needed.

1. One of the best contractor draft reports I have read. I was very impressed with the clarity and organization of the document.

   Action: Thank you!

2.4 Specific Comments: (Mr. Steve Hicken, Hill AFB EMR)

Pg 2-5, Sec 2.2.2: only one interceptor trench is planned for the plume area.

Action/Revision: The sentence has been corrected. See item 1. under Section 2.2.

Pg 2-9, Fig 2-4: diagram needs a scale and axis labels.

Action/Revision: The figure has been revised. See item 2 under Section 2.2

Pg 2-11, Fig 2-5: misspelling of Foulois Drive.

Action/Revision: This figure, now numbered as Figure 2-6, has been corrected to reflect the proper spelling of "Foulois Drive", and is attached for your review. The spelling of "Dissolved Phase" has also been corrected.

Pg 3-14, Table 3-3: hydraulic conductivity for SB-6 should be 26.9 ft/day.

Action/Revision: The table has been corrected to reflect the correct hydraulic conductivity for SB-6.

Pg 3-22, Fig 3-8: needs scale and axis labels.

Action/Revision: The figure has been revised to include a scale and axis labels, and is attached for your review. See item 4 in Section 2.3 above.

Pg 3-23: missing this page.

Action/Revision: This page must have been inadvertently left out of your copy of the draft report. We apologize and have attached the page for incorporation into your copy of the draft final report.

Pg 4-22, Fig 4-6: no axis or scale on this Figure.

Action/Revision: The figure has been revised to include a scale and axis labels. See item 12 in Section 1.2.

Pg 5-4, Fig 5-1: extraction and injection wells are backwards? Also SB-1 on the extraction side should be SB-2. There are other references to the injection and extraction well fields that will need to be corrected if Fig 5-1 isn't backwards.

Action/Revision: The well labels in the figure are reversed. The figure has been revised, see item 18 in Section 1.2.

Pg 5-10, Table 5-3: misspelled Solubilization in the title of the table.

Action/Revision: The spelling of "Solubilization" in the table title has been corrected. See item 21 in Section 1.2 above.

Pg 6-10, Sec 6.3.1.2: reference to Table 6-3 should be to Table 6-6.

Action/Revision: The text has been corrected to refer to Table 6-6.

Pg 6-28, Figure 6-10: Heading and Table are on separate pages.

Action/Revision: The table is now presented on one page.

3.0 INTERNAL REVIEW REVISIONS

The follow items were revised, or added in the text of the Final Report in response to an internal review of the Draft Final by all of the contributing authors. Minor editorial changes, typographical corrections, and small formatting revisions are not included in this list.

3.1 Figures

Figure Number	Revisions/Corrections
2-1	The general OU2 area is now shown as a rectangle rather than a shaded circle. The revised figure is attached.
2-3 (new)	A site map of OU2 has been added as Figure 2-3. This plan view showing the AFCEE demonstration area and the surface facilities at the site, is designed to help the reader identify the important features discussed in the text. Subsequent figures in Section 2.0 have been renumbered to reflect the addition of Figure 2-3. The new figure is attached.
2-7 (new)	A map showing the water-table surface at OU2 has been added to Section 2.4.2 The new figure is attached.

3-1	Soil boring SB-7 has been added to the figure and the legend. The revised figure is attached.
3-9(new)	An index map has been added to show the cross-section lines in plan view. Subsequent figures in Section 3.0 have been renumbered to reflect the addition of Figure 3-9. The new figure is attached.
3-10(formerly 3-9)	Cross-section B-B' has been re-labeled as cross-section A-A'. A dashed-line representing the approximate water-table during the SEAR floods has been added to the figure. The revised figure is attached.
3-11(formerly 3-10)	Cross-section C-C' has been re-labeled as cross-section B-B'. A dashed-line representing the approximate water-table during the SEAR floods has been added to the figure. The revised figure is attached.
4-10	A scale and north arrow have been added to this figure. The revised figure is attached.
5-5	A scale and north arrow have been added to this figure. The revised figure is attached.

3.2 Text

Item	Page	Section/ Paragraph	Line	Action/Revision
1	xvii - xx	Executive Summary	NA	The executive summary has been rewritten.
2	Var- ious	NA	NA	Throughout the text, the word "aquitard" has been changed to "aquiclude" in describing the Alpine Formation at OU2. The definition of aquiclude is "a body of rock that will absorb water slowly but will not transmit it fast enough to supply a well or spring" (Bates, R.L., and Jackson, J.A., editors, 1984, Dictionary of Geological Terms, 3rd edition, prepared by the American geological Institute), which is a more accurate description of the clay deposit that acts as a capillary barrier able to support DNAPL pools over 10 ft in depth.
3	Var- ious	2.0	NA	References to International System (SI) units have been removed from the text to maintain consistency with the rest of the document, in which English units are used.
4	3-13	3.3.1/2	4	The sentence has been amended to state that the system was allowed to equilibrate before the slug test was initiated, and that for "...an aquifer as transmissive as the one being tested at OU2, equilibrium was re-established rapidly, on the order of about one minute."
5	3-14	Table 3-3	NA	Table 3-3 and the discussion of the slug test results have been moved to from Section 3.3.1, which deals with test methodology, to Section 3.4.2.2, which contains the results of the hydrogeologic testing. The table is

Item	Page	Section/ Paragraph	Line	Action/Revision
				renumbered as Table 3-4.
6	3-18	3.3.3	NA	The heading of Section 3.3.3 has been revised to read "Conservative Tracer Test" to avoid confusion with the Partitioning Tracer Tests (PITTs) conducted later as part of the actual SEAR demonstration.
7	3-18	3.3.3/2	4	The sentence discussing the tracer results in the form of a Peclet number has been moved to from Section 3.3.3, which deals with the tracer test implementation, to Section 3.4.2.2, which contains the results of the hydrogeologic testing. A paragraph has been added to the end of this section to describe how this conventional tracer test conducted during site characterization activities was used to help design the SEAR demonstration.
8	5-9	Table 5-2	NA	The listing of H_2SO_4 as a preservative has been removed from this table. Acidification of the water samples was not required because of the rapid analysis turn around, and the large concentration of VOCs in the samples. The word "ice has been replaced with 4° since the samples were kept in a refrigerator in the field laboratory on site.
9	5-22	5.	2	The term "overhead vapor losses" has been clarified for the reader by adding "from the phase separators (from volatilization of the contaminants during the treatment process)" to the end of the sentence.
10	5-22`	5	4	The text has been revised to state that the anomaly in the surfactant recovery curve shown in Figure 5-10 should be attributed to the extraction of surfactant left in the "dead zone" around the extraction well SB-1 while it was inoperative, rather than an accumulation of surfactant created by the gradient induced by the other two pumping wells.
11	6-1	6.0/1	NA	The introductory paragraphs have been rewritten to clarify the purpose of the intermediate PITT, and to make the text more succinct and clear.
12	8-1	8.0	NA	This section has been renamed "Comparison of SEAR Cost and Performance with Traditional Pump-and-Treat Remediation".

The measured TCE concentrations in the effluent from the steam stripper are shown in Figure 7-10. Results are provided for both grab samples collected from the stripper bottoms and cumulative samples collected from the 4,000 gallon effluent storage tank. Despite the high TCE concentrations to the stripper, the effluent remained well below the discharge limit of 16 ppm. The relatively poor observed performance prior to initiation of surfactant injection was due to operational problems with the treatment equipment, which were resolved before surfactant injection began.

As was done for the Phase I work, the measured influent concentrations and the recorded operating conditions were used to model the stripper performance with the ASPEN Plus simulation package discuss in Section 7.2.2. Figure 7-10 compares the model predictions with the measured data. Both baseline (no surfactant) and test conditions were modeled.

The predicted effluent concentrations during the surfactant flood follow closely the best actual measured performance. However, there was clearly a significant scatter of actual performance above the predicted behavior. This scatter is attributed to the occasional fluctuations in operating conditions observed due to sediment buildup in the preheater on the stripper feed stream. Clearly, these sorts of operating fluctuations would need to be eliminated in a full-scale application of surfactant flooding.

7.4.3 Predicted Impacts on the IWTP

The treated effluent from OU 2 was pumped through a pipeline to the Industrial Wastewater Treatment Plant (IWTP) at Hill AFB. At the IWTP the OU 2 effluent is combined with other groundwater and wastewater streams and further treated by air stripping, metals coagulation, and GAC adsorption. The SEAR Work Plan did not anticipate tracking the IWTP influent and effluent during the SEAR demonstration, and so this data was not collected. Prior to the demonstration, the IWTP was consulted and given estimates of contaminant loadings, which they approved. However, a general discussion of the potential impact of the surfactant and IPA in the effluent water from OU 2 on these operations is discussed below.

Normal wastewater flow rates through the IWTP are 250 to 300 gpm. Thus, the 10 gpm effluent from OU 2 were ~~be~~ diluted by a factor of at least 25 in the equalization tanks at the front end of the IWTP. As a result, the maximum predicted concentrations of surfactant and IPA in the wastewater treatment units were 1,600 ppm each during the Phase II Demonstration.

Two potential impacts of the surfactant on the air stripper at the IWTP were considered. First, the surfactant could reduce the stripping efficiency, if the surfactant concentration were above the CMC. However, the predicted concentrations in the combined wastewater would be significantly below the CMC of the sulfosuccinate, which is approximately 0.4 wt% (4,000 ppm). At this concentration there should be a minimal effect on stripping efficiency. The second potential impact of the surfactant on the air stripper could be inducement of foaming. However, at the predicted concentrations the sulfosuccinate would have been below the CMC, which was not expected to induce significant foaming.

The air stripping operation at the IWTP removed some of the IPA from the water during treatment. The efficiency of removal was not predicted. Surfactant has a negligible volatility, so it would not be removed by air stripping.

The surfactant and IPA may have had an impact on the carbon adsorption unit, in that they could increase the carbon utilization rate. If the constituents were to stick tightly to the carbon, it would occupy surface area that would otherwise be utilized for removal of other organics in the waste stream. However, because of their relatively large solubilities in water, surfactants and IPA were not expected to adsorb very efficiently onto carbon and probably were easily displaced by other organics that stick more tightly. Thus, it is likely that these constituents passed through the carbon adsorption unit and appeared in the effluent from the IWTP.

Since the surfactant and IPA were not likely removed from the wastewater stream as they passed through the IWTP, the total organic concentration in the effluent from the IWTP likely increased during the pilot studies. This potentially increased the BOD and COD of the effluent by several hundred mg/l. The potential impacts on discharge criteria from the IWTP were evaluated.

The discharge limits for the IWTP, issued by the North David County Sewer District, are presented in Table 7-3.

Table 7-3 IWTP Discharge Limits

Pollutant	Daily Maximum	Monthly Average
BOD	7,500 lb/d	6,000 lb/d
TSS	1,700 lb/d	1,500 lb/d
O&G	100 mg/l [1]	200 mg/l [2]

[1] Petroleum-based O&G.

[2] Animal/vegetable-based O&G.

For the Phase II Pilot Demonstration, the maximum quantity of surfactant recovered during any 24-hour period was approximately 2,400 pounds. Assuming a BOD-to-organic ratio of 1.0, the surfactant represented approximately 32% of the daily-maximum BOD discharge limits for the IWTP. IPA was also injected into the aquifer and recovered with the groundwater during the Phase II Demonstration. The maximum quantity of IPA recovered during any 24-hour period is predicted to have been approximately an additional 2,400 pounds. However, some of the alcohol may be removed from the water during air stripping at the IWTP. Thus, the maximum predicted impact on operation of the IWTP would be a short-term increase in the BOD of their discharge by as much as 4,00 lb/d. This analysis was presented to Hill AFB prior to the Phase II demonstration. The IWTP did not report compliance problems during the demonstration.

4,000

The membrane treatment system which is represented on both cases is included to recover the surfactant from the aqueous effluent from the stripper. The objective in using the membrane system is to concentrate the surfactant to a level where it can be reinjected.

Preliminary mass balances and equipment sizing for the steam stripper and the air stripper have been conducted for the two cases represented in Figures 8-1 and 8-2. ASPEN Plus simulations were conducted using the design equations presented in Section 7 of this report. The mass balances for these two cases are presented in Tables 8-2 and 8-3 respectively. The corresponding equipment sizes for both cases are presented in Table 8-4. It is observed that the steam stripper requires 40% of the packing depth and half the column diameter as the air stripper to achieve the same effluent criteria, as specified in Table 8-1. The difference in required packing depth is due to the much higher TCE volatility observed at steam temperatures. The difference in required column diameter is due to the high air flow rates required for air stripping.

It should be noted that in the air stripper system there is no effective provision for cosolvent recovery. Most of the cosolvent (about 75%) leaves the stripper in the aqueous effluent.

8.4.3 Cost Analysis

A preliminary cost comparison between the two case of steam stripping and air stripping has been conducted. For the design basis presented in Table 8-1, the preliminary basis for cost comparisons is presented in Table 8-5 and preliminary cost estimates for both cases are presented in Table 8-6. Both purchased equipment costs and operating cost estimates are provided. Operating costs are given on a per month basis, assuming 24-hour per day operation.

Additional treatment costs for the stripper bottoms are not shown in Table 8-6. However, because of the significant concentrations of surfactant and IPA in this discharged stream, some additional treatment is likely to be necessary. At Hill AFB this stream was discharged to the on-base Industrial Wastewater Treatment Plant (IWTP) and subsequently to a municipal treatment plant. A typical incremental cost for treatment of organic carbon in large wastewater plants is $0.33 per lb ~~at~~ of organic carbon. This would translate to an additional $57,000 per month for the air stripper effluent and $40,000 per month for the stream stripper effluent. However, appropriate costs can be highly variable, depending on the specific treatment methods utilized and the spare capacity available.

99.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 DNAPL Site Characterization and Remediation

This report began with the 1989 prognosis of Mackay and Cherry that "*very little success has been achieved in locating the subsurface (DNAPL) sources, let alone removing them.*" In the seven years following this bleak assessment, the PITT was developed at UT and applied by a number of universities and INTERA at several sites, including Hill AFB (OU2 and OU1) and USAF Plants 4 (Fort Worth TX) and 44 (Tucson AZ). It has been demonstrated that the PITT can provide critical information on the location, spatial distribution and volume of DNAPL in alluvial aquifer systems. The development of the PITT has in turn allowed the successful use of SEAR. Without the information on volume and distribution which the PITT provides, surfactant floods would have to be designed blindfolded. Once it was possible to collect the information necessary to design surfactant floods for the removal of DNAPL from alluvium, the act of removing the DNAPL sources became a practicable matter, as has been shown with this Hill demonstration.

Therefore, the necessary conditions for the successful employment of SEAR in alluvial aquifers are:

1. the DNAPL zone is well characterized in terms of the spatial distribution and total volume of DNAPL and the hydraulic and capillary properties of the alluvium trapping the DNAPL, and
2. such characterization is incorporated into a robust design of solubilization using predictive, numerical simulation and laboratory testing and experimentation which result in the efficient sweeping of the DNAPL zone by the surfactant flood.

There is a strong tendency to attempt to reduce remedial costs by cutting back on site characterization expenses. It is apparent that the remediation of sites contaminated with chlorinated solvents requires the most detailed of site characterizations, preferably using innovative (e.g., PITTs) as well as traditional methods (e.g., aquifer tests). The results of this site characterization should be incorporated into a "geosystem" model of the DNAPL zone which is then used for the design and analysis of the surfactant flood.

9.2 Surfactant-Enhanced Aquifer Remediation

- The careful and exhaustive approach (i.e., laboratory experimentation and numerical simulation) used in the design of the two surfactant floods at Hill indicates that >90% removal of DNAPL from alluvium is technically practicable.

- SEAR is a viable remedial option for DNAPL contamination of alluvium. Its employment is likely to be a necessity at sites with substantial DNAPL contamination, such as Hill OU2, in permitting natural attenuation to remediate effectively the downgradient, dissolved-phase plume.

- A properly designed surfactant flood, such as both of those conducted at Hill, will show no evidence of surfactant gelling, precipitation or liquid crystal formation, nor of head loss between injection and extraction wells, nor of bypassing of low-permeability zones.

- Approximately five gallons of DNAPL was left remaining in the alluvium following the two surfactant floods. An additional day of surfactant flooding would have removed this mass, however the design underestimated the number of pore volumes required to completely clean the aquifer. Only following the interpretation of the second PITT was it determined that approximately five gallons remained in situ. Because this demonstration is in fact a pilot-scale test, a scaled-up surfactant flood at OU2 would be designed at 3 pore volumes not 2.4.

- Pump-and-treat remediation would need up to four years to remove this same mass, assuming it is present in the alluvium as residual DNAPL. Water flooding~~Waterflooding~~ the alluvium would reduce this duration to under one year.

- Steam stripping is the preferred treatment process for the effluent from a surfactant flood in that it has been shown to reduce TCE levels in the effluent from approximately 8,000 mg/L to 0.1 mg/L.

- Surfactant-enhanced aquifer remediation of TCE-contaminated alluvium was implemented at Hill AFB OU2 for $1800 per gallon of TCE solubilized, recovered and treated. This compares favorably with costs for pumping-and-treating solvent-contaminated groundwater in alluvial aquifers which costs in the range of $20,000 to $40,000 per gallon of solvent recovered and treated. Treatment costs for pump-and-treat remediation which rely on a 30-year duration of remediation are wholly unreliable because of an absence of knowledge of DNAPL mass in the subsurface.

9.3 Recommendations for SEAR in DNAPL-Contaminated Alluvium

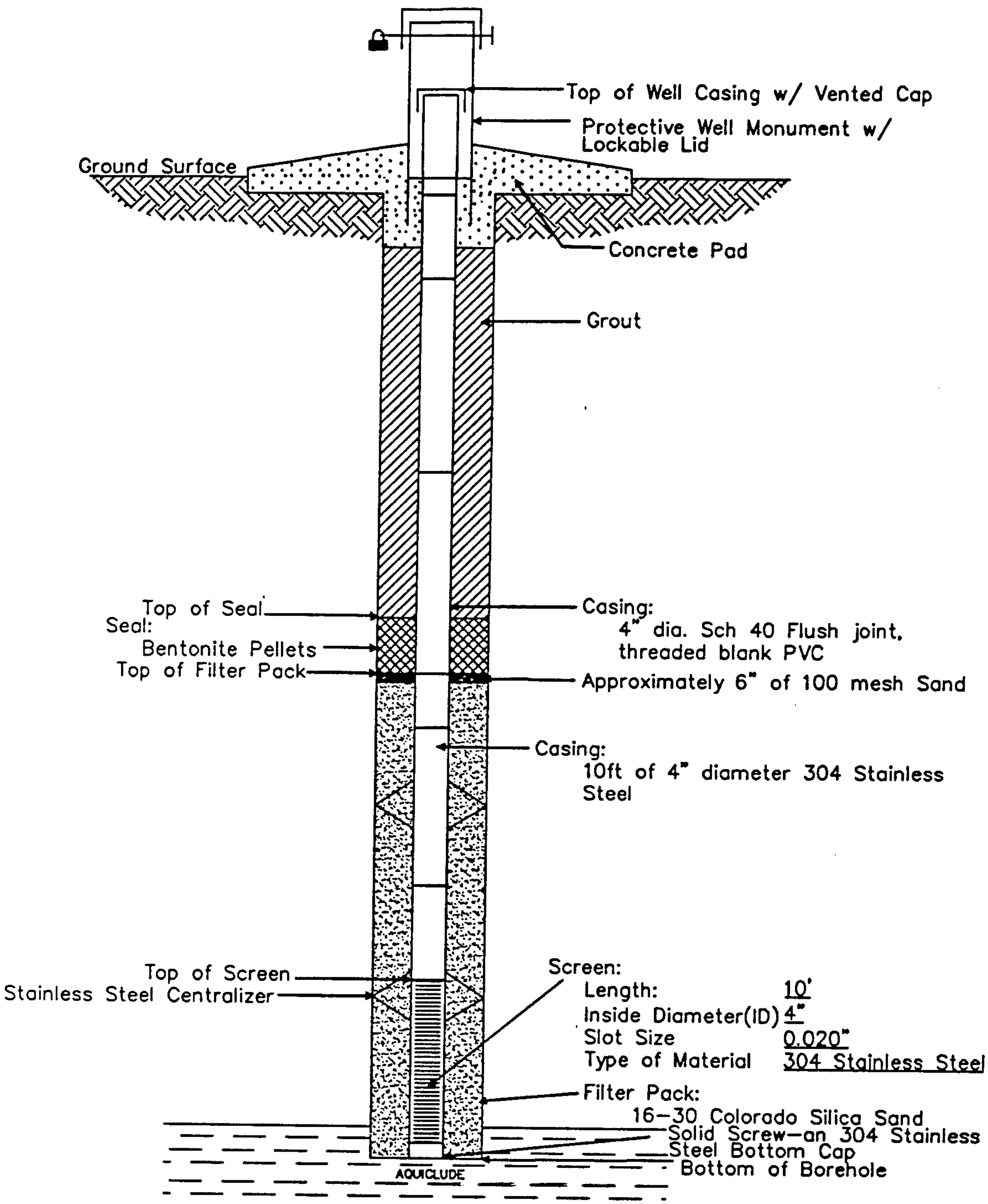
1. ***Site Characterization:*** Traditional methods have rarely provided the information needed to characterize DNAPL-contaminated sites in terms of the spatial distribution and volume of DNAPL. A DNAPL site may be said to be fully characterized when the spatial distribution of residual DNAPL saturation has been mapped and the total volume of DNAPL is known within an error of 50%, i.e., similar to that which we know the hydraulic conductivity of alluvium by interwell hydraulic interference testing. To achieve this level of knowledge of site conditions, it is necessary to use partitioning interwell tracer tests.

2. ***Design:*** Results of such characterization must be incorporated into a robust design model for solubilization using predictive, numerical simulation and laboratory experimentation. This model is known as the geosystem model. It incorporates both basic data about the site, e.g., the hydraulic conductivity and DNAPL distribution, as well as functional requirements for simulating surfactant flooding and multiphase flow, e.g., relative permeability functions and phase behavior of the surfactants with the DNAPL. Furthermore, the approach to design taken by UT indicates that (1) phase behavior testing, (2) alluvial column experiments, and (3) numerical simulations of groundwater flow, tracer testing and surfactant flooding are essential for successful surfactant-enhanced aquifer remediation.

3. ***Hydraulic Control:*** It is also mandatory that the injection-extraction geometry for PITTs and SEAR should be carefully designed to ensure good hydraulic control so that tracers and surfactant are directed as intended through the DNAPL zone. A line drive of three injection and three extraction wells is particularly appropriate for such purposes. A simple well pair often cannot exert the required hydraulic control over the injected tracers or surfactants, particularly if there is any unexpected hydraulic disturbance to the flow field.

4. ***Wellfields:*** The use of existing wells rather than the installation of new, special-purpose wells is a false economy. Existing wells are often poorly completed and/or require extensive rehabilitation. In DNAPL remediation studies such as this, it is essential that the remediation team supervise the drilling and coring of the boreholes so that they can inspect the alluvial

materials first hand, then preserve cores for analysis, and finally install wells to specifications appropriate to SEAR.



FILE: FIG3-2.dwg

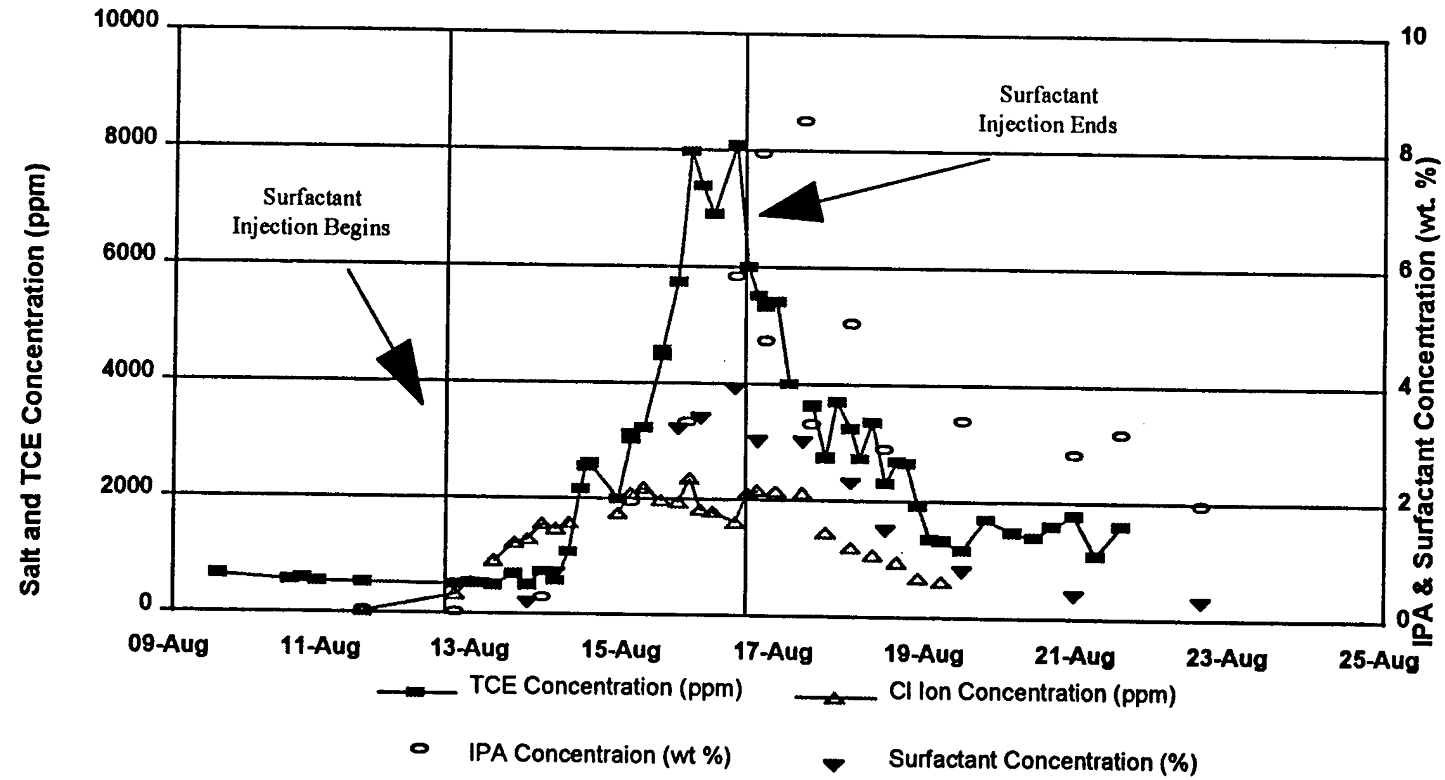
DATE: 10/09/97	**Injection/Extraction Well Construction Detail**
REF: TAF 105 99999	
INTERA	**Hill AFB AFCEE SEAR Demonstration** — **Figure 3-2**

errors in the GC measurements. Since the concentrations of VOCs in the effluent ranged~~were enhanced~~ from about 800 mg/L to 39,000 mg/L, dilution of the samples was required before analyzing them in the GC. Small errors in dilution can cause relatively large errors in measurement of the effluent contaminant concentration. ~~Systematic errors induced by the presence of surfactant in the effluent can also induce errors in measured VOC concentrations.~~

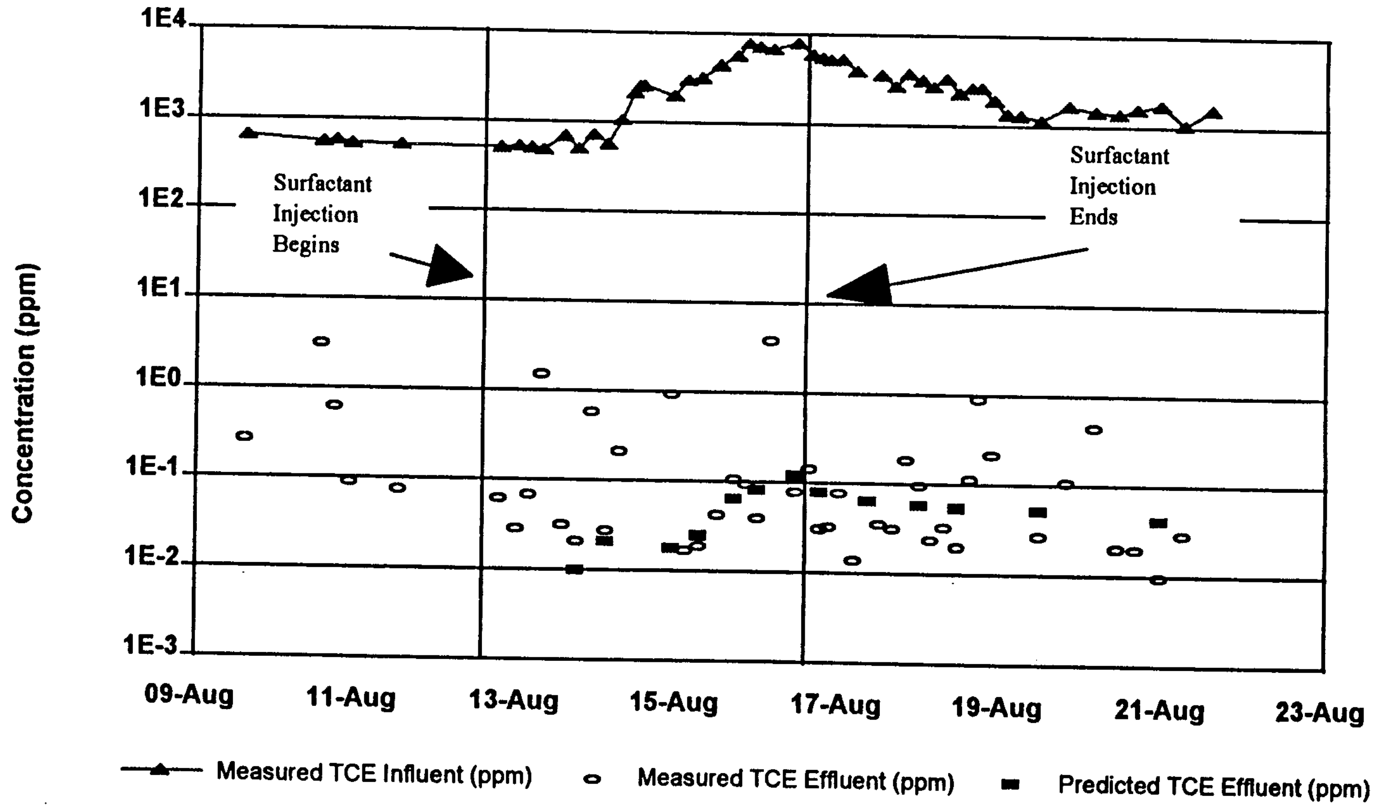
A high level of QA/QC was self-imposed by INTERA for these data. Normally, analytical data generated by a field laboratory using non-standard analytical procedures must meet Level II requirements. Instead, Level III, a more stringent level of QA/QC, was established. Level III is normally applied to standard methods of analysis. No standard methods are available for gas chromatography (GC) analysis of the alcohol tracers (from which the VOC concentrations were also analyzed). The methods used had to be specifically developed for the application to prevent analyte interferences and to reduce analytical costs. The only difference between Level III and Level IV data (the highest level of data quality) is the level of QC documentation procedures. The QC documentation required in Level IV is in accordance with EPA CLP protocol. For the benefit of the reader, much of the QC documentation required of Level IV data is presented in Appendix B. Nearly continuous 24-hour GC analyses were needed to accommodate the short sample holding times of the volatile organic compounds (VOCs) and the high number of samples collected. Samples were automatically analyzed overnight. As a result, an occasional quality control limit for a given analyte was exceeded. The QAPP allows for such exceedances as long as the appropriate data in the batch are flagged accordingly. In most cases, the exceedance does not mean that the results of the samples in the batch are inaccurate. Often the exceedance was due to degradation of a QA sample, an improperly prepared QA sample, or an anomalous injection. Control limits on the recoveries of calibration check standards were set at 80-120%. These control limits were rarely exceeded. Quality assurance data relevant to the sample concentration data are tabulated in hard copy in Appendix B.

B~~Moreover, b~~ecause the extraction wells were overproducing, they were extracting VOC contaminated water from outside the swept volume, thereby recovering VOCs from zones which had not been swept by the surfactant, leading to an overestimation in DNAPL recovery estimates. Hence, well effluent and SRS measurements are not very accurate predictors of DNAPL recovery.

However, the most important performance assessment for surfactant flooding or any DNAPL recovery technology is the final residual DNAPL saturation remaining *in situ* at the completion of remediation. This can best be assessed by using PITTs and will be discussed in the following section.



DATE: 10/15/97	Composition of the Steam Stripper Influent Stream During the Phase II Demonstration
REF: TAF105 99999	
FILE: 7-910.PPT	
INTERA	Hill AFB, Utah — Figure 7-9



DATE: 06/09/97	Measured and Predicted TCE Concentrations in the Influent and Effluent from the Steam Stripper During the Phase II Demonstration
REF: TAF105 99999	
FILE: Fig7-6-10.PPT	
INTERA	Hill AFB, Utah — Figure 7-10

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solutions to remediate DNAPL to residual saturations less than 0.1% while showing desired characteristics such as minimal adsorption, low hydraulic gradients during surfactant flooding, and no permeability reduction by surfactant flooding. These results were then used in the UTCHEM simulations of the SEAR demonstration to select the optimum surfactant solution for the project.

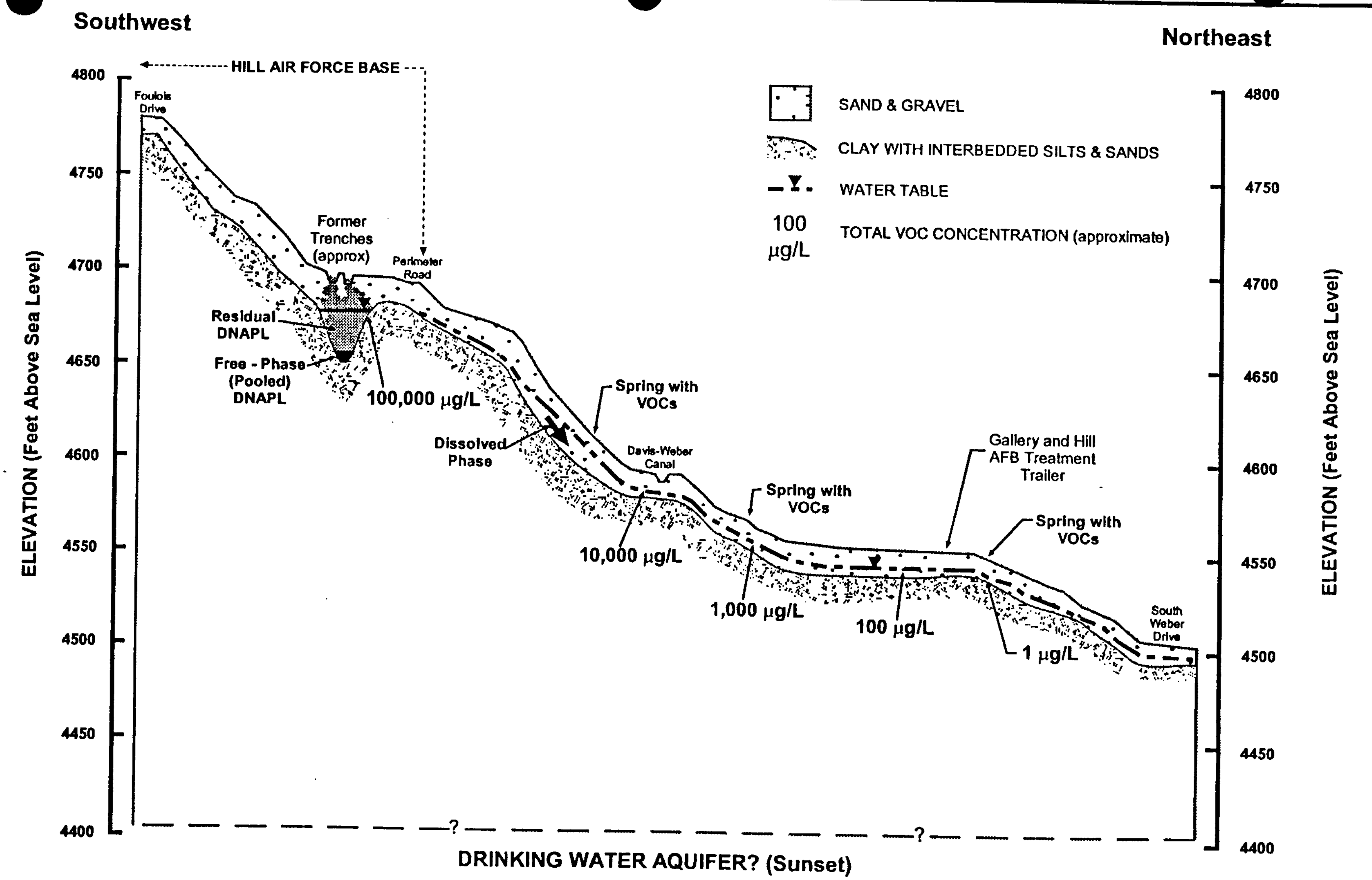
During the column floods, DNAPL recovery was assessed by both mass balance measurements and partitioning tracers where possible. In experiments using contaminated Hill alluvium where mass balance measurements were not possible, partitioning tracers were used to assess the remediation performance. The pressure drop across the columns was measured during each surfactant flood to ensure that hydraulic gradients did not exceed values achievable under actual field conditions, and to monitor for potential injectivity and permeability problems such as liquid crystal/gel/emulsion formation in the column. During several experiments, the column's post-surfactant permeability was compared to the initial permeability to ensure that the surfactant solution did not cause plugging in Hill alluvium. One experiment was carried out at 12.2 C to evaluate surfactant performance at the ambient aquifer temperature.

In order to measure surfactant adsorption, C^{14} labeled surfactant was injected into several columns. Tritium was used as the conservative tracer in these column experiments. The tritium and surfactant concentration history during the surfactant flood and post surfactant water flood for one such column experiment is shown in Figure 4-5. The surfactant adsorption measured in this experiment was less than 165 mg of surfactant per kilogram of aquifer sediment. In a field application such as that at Hill OU2, this would correspond to surfactant loss of less than 0.3%.

Many of the column experiments for this project were conducted with a surfactant solution containing a polymer (xanthan gum - a food grade additive). The addition of polymer increases the viscosity of the surfactant solution, which in turn improves the sweep efficiency of the flood. For example, as little as 500 mg/L xanthan gum added to a surfactant solution can increase its viscosity by a factor of 5. The increase in viscosity mitigates the tendency of the surfactant solution to flow preferentially in higher permeability zones as it travels through the heterogeneous alluvium. The result is that the surfactant solution is forced into the lower permeability zones as it flows through the porous media. Originally intended to be used as an additive for the SEAR demonstration, polymer was not actually included in the final demonstration design due to budgetary constraints.

A comparison of the initial permeability and the post-surfactant permeability for two column experiments is shown in Table 4-6. The errors in the permeability measurements are usually on the order of 10%. In addition, xanthan gum polymer was used in the experiments listed in Table 4-6. Since the displacement of polymer by water is a very inefficient process, it takes about 50-60 pore volumes of water to completely displace the polymer from even a small column. In the experiments listed on the table, this many pore volumes were not put through the columns, hence some loss of permeability was observed. This loss of permeability accounts for the observed reduction in permeability presented on the table.- In both experiments, low hydraulic gradients were measured during the surfactant flooding in the columns, indicating that a negligible reduction in permeability occurred~~was observed~~, ~~indicating that surfactant flooding restored the soil in the column to its original condition. This conclusion was further substantiated by the low hydraulic gradients measured during the surfactant flooding in the columns~~. In experiments in which polymer was not used, induced gradients were always less than 0.3 cm/cm and in experiments utilizing surfactant/polymer solutions, the induced gradients were between 0.8 and 1.2 cm/cm. Gradients in this range are easily achieved in the field. A summary of the final DNAPL saturation after surfactant flooding for selected column experiments is given in Table 4-7. The low saturations listed in this table demonstrate that the surfactant flooding reduced DNAPL saturations in the columns to as low as 0.02%. Apparent DNAPL saturations on the order of 0.04% are so low as to be in the noise at the low end of the measurement technique, and correspond to a recovery of 99.9% of the DNAPL. It is quite likely that for these columns, the remaining contaminant was in actually retained in the Teflon end pieces rather than as trapped ganglia in the pores of the sediment. This is the first time DNAPL recoveries this high and residual DNAPL saturations this low have been reported in the literature.

Figure 4-5 —Comparison of Normalized Tritium and Surfactant Concentration During Surfactant Flooding in a Column



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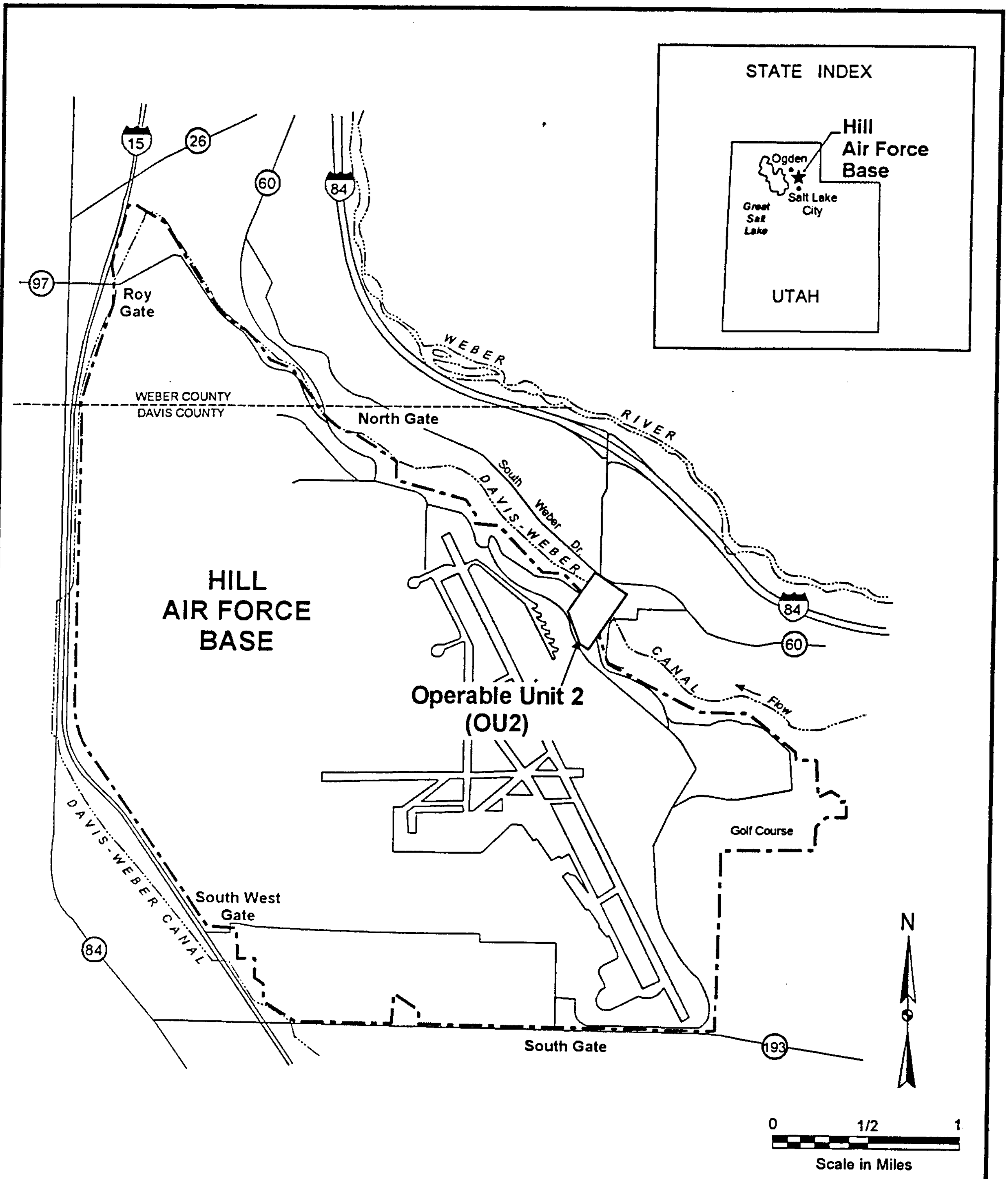
Generalized Cross-Section of OU2

(Modified from Radian, 1992.)

Hill AFB, Utah

0 100 200 300
Feet
Vertical Exaggeration: 4X

Figure 2-6



DATE:	10/09/97
REF:	TAF105.99999
FILE:	HillMAP.xar

INTERA
A Duke Engineering & Services Company

Location Map of Hill Air Force Base

(Modified from Radian, 1992.)

Hill AFB, Utah

Figure 2-1

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EXECUTIVE SUMMARY

There is a consensus within the technical community that the pump-and-treat remediation of trichloroethene (TCE) and other chlorinated solvents fails to remove the source of the dissolved-phase plumes that are evident at many industrial sites and USAF bases. As Mackay and Cherry (1989) wrote: "...very little success has been achieved in even locating the subsurface sources (of the solvents), let alone removing them." It is now understood that dissolved-phase TCE plumes and those of other chlorinated solvents are due to the dissolution in ground water of these solvents, present, but not necessarily observed, in the subsurface as dense, non-aqueous phase liquids or DNAPLs. Dissolution of the trapped DNAPL occurs by ground water either percolating through DNAPL zones in the unsaturated zone of the aquifer above the water table or flowing through DNAPL zones in the saturated zone of the aquifer.

Within the USAF the problem is perceived more in terms of a budgetary crisis arising from the failure of pump-and-treat remediation to remove the DNAPL source zones within a short period of time. This position is most clearly stated in the draft position paper (October 1996) of the Defense Department's DNAPL Integrated Product Team (IPT). The IPT reported that a typical pump-and-treat system costs $400,000 to $500,000 per year to operate and is usually planned to operate for 30 or more years. Furthermore, USAF installation cleanup budgets are being increasingly used for the operation and maintenance (O&M) of pump-and-treat and soil-vapor extraction systems such that "*O&M costs will soon make new cleanup efforts impossible due to budgetary constraints.*" Consequently, the IPT concluded that "*more cost-effective technologies for solvent detection and remediation are needed now.*"

During the summer of 1996, INTERA conducted a successful demonstration of surfactant-enhanced aquifer remediation (SEAR) in collaboration with the Center for Petroleum and Geosystems Engineering at the University of Texas at Austin (UT) and with Radian International. The US Air Force Center for Environmental Excellence (AFCEE) funded the necessary DNAPL-zone characterization and surfactant-flood demonstration. The Center for Petroleum and Geosystems Engineering at UT funded the design of the surfactant floods, and Hill AFB near Ogden, Utah provided extensive logistical support. As is documented in this report, SEAR meets the requirements set down by the IPT for cost-effective detection and remediation of chlorinated-solvent DNAPL zones.

The demonstration was conducted at Operable Unit 2 (OU2) at Hill AFB, which had received large volumes of chlorinated solvents from degreasing operations conducted at the base. OU2 is underlain by an alluvial sand aquifer confined on its sides and

6 T

below by thick clay deposits that form a capillary barrier to DNAPL migration. The hydraulic conductivity of this alluvium is in the range of 10^{-5} to 10^{-4} m/s. This aquifer contains tens of thousands of gallons of DNAPL, seventy percent of which is TCE.

A demonstration area was developed during the Spring of 1996 by installing a set of three injection wells and three extraction wells in a 3 x 3 line-drive geometry. This well field also contained one hydraulic control (injection) well to prevent the upgradient flow of tracers and surfactant, and one interwell monitor well. The distance between injectors and extractors was 20 ft; the distance between individual injectors and individual extractors was 10 ft; the water table depth was approximately 25 ft below ground surface; and there was a 4-ft thick zone of free-phase and residual DNAPL approximately 45 ft below ground surface. The screened intervals of the injectors and extractors were completed in this DNAPL zone and extended some distance above it. Prior to the demonstration, about 500 gallons of free-phase DNAPL were pumped from the recently-installed well field and sent for incineration.

The demonstration was conducted in two phases. The first of these phases comprised a partitioning interwell tracer test (PITT) followed by a DNAPL solubilization test, both of which were conducted in May and early June 1996. The PITT determined the spatial distribution and volume of DNAPL in the test zone of the alluvial aquifer. The solubilization test verified the efficiency of the selected surfactant, determined if the surfactant would cause the deflocculation and mobilization of fine-grained particles resulting in a reduction in permeability of the aquifer, and also addressed the issue of the effect of the surfactant-rich effluent on the efficiency of the steam stripping system at the site. This test involved the injection of an 8% surfactant solution into one injection well at 2 gpm for 0.6 days, producing an interfacial tension of 0.1 dynes/cm between the surfactant solution and the OU2 DNAPL.

The PITT indicated that there was a total of 346 gallons of DNAPL in the 4-ft thick test zone with an average residual DNAPL saturation of 20% (i.e., S_r = 0.20) or approximately 4% when measured over the whole, 20-ft thick, swept volume of the aquifer (i.e., S_r = 0.036). The solubilization test showed the selected surfactant to be extremely effective, and that there was no significant head loss due to mobilization of fines across the line-drive test zone. Furthermore, the steam stripper at OU2 readily treated the surfactant-rich waste waters.

The results of the Phase I field operations were used to finalize the design of the Phase II surfactant flood. The Phase II flood, the purpose of which was to remove all remaining DNAPL from the test zone in the alluvium, was preceded and followed by PITTs so that the performance of the flood could be assessed. The surfactant flood consisted of the injection of a solution of 8% surfactant, 4% isopropyl alcohol and 0.7%

NaCl, producing an interfacial tension of 0.02 dynes/cm. The Phase II field operations lasted for 30 days, of which surfactant injection at 7.5 gpm accounted for 3 days (i.e., 2.4 pore volumes), the follow-up water flood took 5.5 days and the final PITT took 6 days. This final PITT indicated that the average residual DNAPL saturation over the 20-ft thick swept zone of the aquifer had been reduced from 0.036 in early May to 0.0004 in late August in a swept volume of approximately 15,000 gallons. Therefore, the PITTs had shown that the two surfactant floods had recovered 341 of the 346 gallons of DNAPL within the test zone of the OU2 alluvial aquifer. This represents a total recovery of 99% of the DNAPL determined by the Phase I PITT to be present in the test zone of the OU2 aquifer.

Following completion of the field work, it was estimated from analysis of the final PITT that approximately five gallons of DNAPL was left in place at the end of the demonstration. The remediation time for these last five gallons has been calculated for various scenarios - as a pool and as vertical fingers with DNAPL blobs or ganglia of differing lengths trapped within the alluvium. Collectively, these scenarios reveal the relative efficiencies of SEAR versus waterflooding versus traditional pump-and-treat.

For the less probable case of a five-gallon pool of DNAPL remaining at the base of the aquifer (less probable, because such a pool would have been observable in monitoring well SB-6), the injection of 3, rather than 2.4, pore volumes of the surfactant/alcohol solution would have dissolved the pool during the demonstration by extending it a few days to a week at most. If instead, the injection of clean water at 7.5 gpm had been continued at the end of the surfactant flood, the five gallons of pooled DNAPL would have been removed by dissolution over a period of ten years. However, if the site reverted to pump-and-treat remediation with only groundwater extraction, then it would take 50 years to dissolve a five gallon pool of DNAPL.

The second case, the more probable one, is that of five gallons of residual DNAPL distributed throughout the aquifer as blobs or "ganglia" of different geometries and surface area. For this case, the injection of 3, rather than 2.4, pore volumes of the surfactant/alcohol solution would have dissolved the ganglia during the demonstration by extending it a day or two at most. If instead, the injection of clean water at 7.5 gpm were continued, the five gallons of DNAPL would have been removed by dissolution over a period of a few months, but less than one year in total. However, if the site had reverted to pump-and-treat remediation with only groundwater extraction and no injection of clean water, then it would take a few months to up to four years to dissolve the DNAPL.

Thus, over the course of a few months, at a cost of about $3000/gallon, 98.5% of the residual DNAPL was removed. This can be compared with the original USAF estimate for cleanup of the DNAPL that used the traditional time frame of 30 years with a cost of

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recovery now running at $32,000/gallon. The estimate of 30 years was based on a purely speculative estimate of the efficiency of pump-and-treat remediation and has no basis in fact. However, the cost of $32,000 per gallon of DNAPL recovered is similar to other pump-and-treat systems (e.g., McClellan AFB, CA and DOE Portsmouth, OH) that use ground-extraction wells and an air-stripping system to capture and treat TCE plumes. Furthermore, the recovery of some 500 gallons of free-phase DNAPL before the surfactant flood, and therefore prior to its dissolution and subsequent downgradient extraction and treatment, resulted in a cost savings of approximately $15 million to the USAF.

The two surfactant floods conducted at OU2, Hill AFB during the period May through August 1996 demonstrated the technical practicability of removing ~99% of residual DNAPL from alluvium, provided the site in question is well characterized and an exhaustive design protocol is followed. This level of DNAPL-zone remediation has significant implications for the regulatory issues of technical impracticability and natural attenuation.

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August 26, 1997

Mr. Sam Taffinder
AFCEE HQ
AFCEE/ERT
3207 North Road
Brooks AFB, TX 78235-5363

Re: AFCEE SEAR Demonstration
Hill AFB, Utah
Contract No. F41624-95-C-8010

Dear Mr. Taffinder:

We are in receipt of two faxes from you, one dated July 29, 1997 and the other August 20, 1997. These faxes constitute AFCEE's comments to INTERA on our Draft Final Report for the above referenced project. These comments are from AFCEE and also from Hill AFB.

We have examined the comments and appreciate the depth of review conducted by AFCEE and Hill AFB. We have commenced work on making changes to the Draft Final Report based upon these comments. We anticipate we will have the Final Report complete by the third week in October. This schedule is dictated by prior commitments to field work at Hill AFB. This field work will involve the principal authors of the report.

In anticipation of completing the Final Report, we would like to provide excerpts of the corrected draft report to you for your review by the second week in October. This would give you the opportunity to review only the changes we've made, and not the whole report anew. This prior review will ensure that the Final Report is responsive to AFCEE before we complete the final printing.

The vast majority of the comments you've provided are clear to us and we will make the changes and corrections as indicated. In this letter we would like to request clarification on a few of the comments. This will aide us in preparing our corrected draft report. For ease of review, this letter is organized in a similar fashion as the review documents. The comments below are restricted to the July 29, 1997 fax.

Executive Summary (Fax Cover Page): INTERA agrees that the Executive Summary is intended to present an overview of the contents of the report itself and not intended to contain new issues or conclusions. We will amend Section 6.4.3 to discuss our conclusion that an increase in total pore volume would have resulted in a complete removal of the residual DNAPL. In the comments to the Executive Summary it is suggested that this is a "what if" scenario. We will make it clear in the report that this is a conclusion based upon our tests and simulations and not speculation.

In the next paragraph of the executive summary review, it is pointed out that the question of how the remaining 5 gallons of DNAPL will impact the site over time is of great import. We have provided a discussion of this issue in 6.4.3 and will expand that section. However, it should be noted that this discussion is somewhat of a "what if" scenario and it will be difficult to provide a hard discussion. This is due to the lack of knowledge we have in the distribution and state of the remaining DNAPL.

Based on the above, we would like to stimulate additional discourse on these topics before we complete those sections of the Final Report.

General Comments: The second and third paragraphs of the General Comments and Item 39 in the Specific Comments section request additional information concerning the treatment of effluent from the SRS at the base IWTP. We will not be able to address specific IWTP cost issues for the pilot study in the Final Report. Prior to the demonstration, the IWTP was consulted and given rough estimates of contaminant loading, which they approved. This met the requirements of the Work Plan for dealing with the offsite (post SRS) treatment of the waste. The Work Plan did not anticipate tracking the cost of IWTP treatment of the SRS waste stream, and therefore that data was not collected. However, we will be able to provide a rough estimate of IWTP treatment costs for the full scale cost estimate and will make this change to the Final Report.

The first part of the last paragraph of the General Comments is somewhat confusing. Prior to the preparation of the QAPP for this project we discussed with AFCEE the fact that the AFCEE guidance documents for this submittal were designed for RI/FS projects and therefore not entirely appropriate for this work. As a result of the feedback we received from AFCEE, we prepared and submitted a plan more appropriate to the work at hand for review by AFCEE. This document was commented upon, amended, and approved for use by AFCEE prior to it's use on the project. This document was amended for Phase II of the work and again reviewed and approved for use by AFCEE. INTERA requests a clarification of this comment.

As we develop the changes and corrections to the report, we will bring to your attention any issues that may require discussion. We appreciate your guidance on this project and look forward to your comments on the items discussed in this letter. Thank you for this opportunity to be of service.

Sincerely,

Paul B. Cravens

Paul B. Cravens, P.E.
Group Manager
Senior Engineer